1-1-2007

# Industry value at risk in Australia

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# INDUSTRY VALUE AT RISK IN AUSTRALIA

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**This thesis is presented in fulfilment of the requirements for the degree of Doctor of Philosophy**

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**September 2007**

# USE OF THESIS

# ABSTRACT


Value at Risk (VaR) models have gained increasing momentum in recent years. Market VaR is an important issue for banks since its adoption as a primary risk metric in the Basel Accords and the requirement that it is calculated on a daily basis. Credit risk modelling has become increasingly important to banks since the advent of Basel II which allows banks with sophisticated modelling techniques to use internal models for the purpose of calculating capital requirements. A high level of credit risk is often the key reason behind banks failing or experiencing severe difficulty. Conditional Value at Risk (CVaR) measures extreme risk, and is gaining popularity with the recognition that high losses are often impacted by a small number of extreme events.

The management of sectoral concentration is a critical component of risk management, as over concentration in sectors can be a significant contributor to difficulties experienced by banks. There has been no prior investigation of industry based VaR or CVaR metrics in Australia to the author's knowledge. This paper examines both market and credit VaR and CVaR in Australia from an industry perspective using a set of Australian industries. VaR and CVaR are compared between these industries over time, and a variety of metrics are used including diversified and undiversified VaR, as well as parametric and nonparametric CVaR methods. It is important to note that, provided a sufficiently long time period is used, for both credit and market risk there is found to be significant association between diversified and undiversified industry VaR rankings, and between parametric and nonparametric CVaR approaches. This means that bankers can be reasonably confident of the robustness and consistency of any one of these metrics when calculating and applying them over time and across industries.

New CVaR techniques are introduced in this study and compared to existing methodology. This provides banks with a range of methodologies for measuring extreme risk. Significant association is found between new and existing CVaR methods, showing simpler methods to be viable alternatives to more complex methodology.

Whilst industry considerations are very important to banks in modelling credit risk, a study in Australia has shown that incorporation of macroeconomic factors into credit modelling is not favoured by banks. To overcome this problem, we examine the

interaction between sectoral credit and market risk, finding that those industries which are risky from a credit perspective are not significantly different from those which are risky from a market perspective, and we use this relationship to develop a new model that allows the incorporation of market modelled industry VaR factors into credit modelling, without the need for macroeconomic analysis.

Although using Australian indices, the techniques developed in this study have universal application.

# DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgment any material previously submitted for a degree or diploma in any institution of higher education.

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

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# ACKNOWLEDGEMENTS

Firstly, thanks to Dave Allen for his guidance in topic selection and his invaluable assistance and support in his role as supervisor.

Thanks to Professor Lyn Thomas of the University of Southampton and to Dr. Paul Gerrans of Edith Cowan University for their review of the proposal. Their comments and suggestions were of significant benefit in improving content, structure and methodology.

Grateful thanks is given to Standard & Poor's and Moody's Investor Services for information and data provided.

To my mother and father, who put me through my initial degree, I am eternally thankful.

The thesis involved many long hours of work, which impacted on family life. Special thanks to my wife and children for their support and understanding during this time.

# NOTE ON WORD COUNT

Due to the modelling nature of this study, a significant part of this study comprises the models and associated formulas, data analysis and tables. These have been summarised and incorporated in the thesis as picture files. The content of these picture files do not come up in a word count, but comprise approximately 50,000 words, in addition to the thesis text, giving a total word count of 90,000. The modelling summaries represent a small fraction (1.6%) of the total 31 million word count contained within the actual models.

# ACCESS TO INFORMATION

Moody's Investor Services provided the author with a spreadsheet containing individual company data for incorporation into this thesis. This comprised of individual ratings and balance sheet information for rated entities. The spreadsheet is provided subject to copyright. Similar information was provided to me by Standard & Poor's (S&P), contained within their Australia & New Zealand CreditStats publication (2005a). Although the information from these sources was provided to me for the express purpose of inclusion into the thesis, I have in any event ensured that no potential confidential or sensitive individual company information is included within this thesis, as the Moody's and S&P data been aggregated and consolidated together and with other publicly available data, and no individual company data, other than what is publicly available, is shown in this thesis.

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## ABBREVIATION DEFINITIONS

| Abbreviation | Definition | Main Section Reference |
|---|---|---|
| All Ords | All Ordinaries Index: The market indicator for the Australian Stock Exchange consisting of the largest 500 listed companies by market capitalisation | 2.3.1 |
| ADI | Authorised Deposit Taking Institution | 2.2.1 |
| APRA | Australian Prudential Regulation Authority: Australian supervisor of Basel II | 2.2.2.2 |
| ASX | Australian Stock Exchange | 2.3.1 |
| Basel I | Basel I Accord 1988: BIS original capital adequacy framework | 2.2.1 |
| Basel II | Basel II Accord 2004: BIS revised capital adequacy framework | 2.2.1 |
| BIS | Bank for International Settlements | 2.2.1 |
| Calibrated PD | Calibrated Probability of Default: A method derived by this study for estimating default probability values using a table of calibrations between Moody's / S&P credit ratings and KMV EDF | 3.4.2 |
| CDD | Conditional Distance to Default. DD on condition CDD exceeds DD | 3.5.2 |
| CStdev | Conditional Standard Deviation. Standard Deviation of extreme (CPD) returns | 3.5.2 |
| CPV | CreditPortfolioView: A model measuring credit risk which incorporates macroeconomic factors. | 2.5.4.3 |
| CPD | Conditional Probability of Default. PD on condition that CPD exceeds PD | 3.5.2 |
| CVaR | Conditional Value at Risk: Value at risk on condition that CVaR exceeds VaR | 2.7 |
| DD | Distance to Default: approach used by Merton / KMV for estimating how much the market value of a firm needs to fall before default point is reached - an input into the Structural PD calculation | 2.5.4.1 |
| EDF | Estimated Default Frequency: approach used by KMV | 2.5.4.1 |

| Abbreviation | Definition | Main Section Reference |
|---|---|---|
| | to estimate default frequencies from DD, using the KMV historical default database | |
| GICS | Global Industry Classification Standard: A joint Standard & Poor's / Morgan Stanley Capital International Product aimed at standardising global industry classifications, and is the industry code system used by the ASX. | 2.3.1 |
| IRB | Internal Ratings Based: approach to calculating capital adequacy through use of a Bank's own models | 2.2.5.2 |
| KMV | KMV Corporation: Acronym for Kealhofer, McQuown, & Vasicek, the developers of the KMV default measurement model (now owned by Moody's) | 2.5.4.1 |
| LGD | Loss given default | 2.2.5.2 |
| Moody's | Moody's Investor Corporation, Inc.: A company providing credit ratings | 2.5.2 |
| n.d. | Not dated: undated references | References |
| NI | Net income | 2.5.3 |
| PD | Probability of Default. A measure of likelihood of a firm defaulting on it's credit obligations, and used or referred to by various entities/models, including BIS, Merton / KMV, CPV and CreditRisk+ | 2.5.4 |
| RWA | Risk Weighted Assets. Weighting of assets for calculation of capital requirements | 2.2.5 |
| S&P | Standard & Poor's: A company providing credit ratings | 2.5.2 |
| S&P ASX 200 | Standard & Poor's Australian Stock Exchange 200 index considered as Australia's investable equity benchmark | |
| SME | Small and Medium Enterprises | 2.2.5.2 |
| *VaR* | Value at Risk: a measure of maximum expected losses over a given time period at a given tolerance level | 2.4 |

# 1. INTRODUCTION

## 1.1. Background

The Basel Accords have placed a huge focus within the Banking Industry on risk modelling. Banks are required to set aside capital for market and credit risk. There is a significant cost to banks in holding capital, as opposed to being able to get a market return on these funds. Under the Basel II Accord (Bank for International Settlements, 2004) which comes into effect in Australia year end 2007 (Australian Prudential Regulation Authority, 2004b), banks who meet certain credit modelling criteria are able to use internal models to help determine risk weighted capital. This could significantly benefit banks who are able to demonstrate a reduced capital requirement.

The Value at Risk (VaR) approach to risk measurement has gained a great deal of momentum in recent years. VaR calculates maximum expected losses over a given time period at a given tolerance level. VaR has become the recognised standard approach for market risk measurement, and has also been extended to credit risk modelling approaches. VaR calculates maximum expected losses over a given time period at a given tolerance level.

The importance of credit modelling, and the understanding and management of credit risk is highlighted by the statement by the then Deputy Reserve Bank Governor, GJ Thompson (1997): “All of the major periods of stress in Australian Banking have been caused by credit losses”. This view is supported by the then Group General Manager, Financial and Risk Management, Michael Ullmer (1997, p.6) who notes that “there is overwhelming evidence for the potency of credit related losses on the banking system”. Hogan et al. (2004, p.299) note that “an ADI’s survival and ability to compete depends mainly on its ability to maintain a healthy loan portfolio”. Management of sectoral risk is a key component of credit risk management. Jackson (1996, p.42) notes sectoral or regional over concentration as one of the key reasons for 22 banks in the UK failing or experiencing severe difficulty.

Despite its popularity, our literature survey will show that VaR has certain undesirable mathematical properties such as lack of sub-additivity and monotonicity. Furthermore, VaR gives no indication of the losses that might be encountered beyond the threshold amount suggested by the measure. This study features the exploration and application of an alternative to VaR: CVaR (Conditional Value at Risk). CVaR considers extreme events, based on losses exceeding VaR. CVaR studies have traditionally been used in the insurance industry, but are gaining popularity in the Banking industry, with the increasing recognition that losses are often characterised by infrequent extreme events. CVaR does not exhibit the undesirable mathematical properties evident with VaR, and also quantifies the losses encountered in the tail of the distribution.

## 1.2. Objectives

This study has the objective of providing a greater understanding of industry VaR (and CVaR) in Australia from both a market and credit risk perspective, incorporating Equity, Structural and Transition approaches. In addition, the study aims to provide tools (indices and modelling approaches) that can be used to assist risk modellers. Prior studies have shown that different models can provide a wide range of VaR measurements (examples are Beder, 1995 and Hendricks, 1996 cited in Marshall & Siegel, 1996, p.4). Thus, while this study arrives at specific VaR measurements across industries where calculated by models, it focuses on the *relative* VaR ratings (do the models all show higher VaR in certain industries and lower VaR in others even though the actual measurements may differ widely?).

Specifically, objectives are:

1. To provide an analysis of industry VaR in Australia using the 3 approaches. First is the Equity model, a market approach based on the variance-covariance parametric model. Second is the Structural model based on the Merton-KMV Options approach which incorporates both an equity and debt component. Third is the Transition model which is the CreditMetrics Transition Matrix approach, based on credit ratings.

2. To provide an analysis of industry CVaR using each of the above models.

3. To compare outcomes across models, over time, between correlated (diversified) and non-diversified data, and between various statistical techniques (in particular relating to CVaR, such as parametric and nonparametric approaches).

4. To derive specific measurements for VaR and CVaR for each industry and a set of relative market and credit industry indices, which can be incorporated into banks' models.

5. To develop new modelling techniques, where existing methodologies or data limitations do not readily permit the industry VaR and CVaR analysis undertaken in this study, and which new techniques can readily be used by banks or researchers in this area. Specifically this will include techniques which allow the incorporation of CVaR industry measurements into each of the three selected models, and techniques for modelling VaR and Estimated Default Frequencies (EDF) where data is not readily available (for example, KMV EDF factors are available by subscription only).

6. To develop a new Credit VaR and CVaR model using Australian data (but with a universally applicable framework) which includes key elements of the Transition Matrix approach reviewed in this study and incorporates industry indices per 4. above.

7. To identify any key limitations of the models in an Australian context, such as availability of data.

## 1.3. Contributions of the Study

### *1.3.1. Summary of Contributions*

The study provides contributions in 6 key areas (these are all expanded on in section 1.3.3):

1. The study addresses a need for additional research on VaR, CVaR and industry risk in Australia, as identified in the literature survey.

2. The approaches discussed in the study can assist banks in several facets of risk management.

3. The study derives specific industry risk measurement indices using VaR approaches, providing a more cost effective and less modelling intensive approach to existing methods predominantly used in Australia.

4. The study provides insight into the association between credit and market risk and develops a new model combining market and credit approaches.

5. The study develops unique modelling methodologies for the incorporation of CVaR, Default Probability and Conditional Probability of Default (CPD) into Structural and Transition models.

6. Although the study is based on Australian data, it also contributes to international credit risk modelling techniques, as the methodologies have universal application.

### *1.3.2. Original Nature of the Contribution*

The contribution is original in several ways.

1. The literature survey has not identified other research on industry VaR and CVaR in Australia, and the study therefore provides new insights on this topic.

2. As noted in section 1.3.3. below, the study uses different techniques for measuring industry VaR to those currently used in Australia. It arrives at a unique set of industry indices for both market and credit risk in the Australian market, and provides modellers with less expensive and less modelling intensive methods of measuring industry risk.

3. The study examines the association between market and credit risk, and a new credit model is developed, combining market and credit approaches.

4. Unique methods are developed for the incorporation of CVaR, Default Probability, and Conditional Probability of Default into Structural and Transition modelling approaches.

### *1.3.3. Contribution Details*

This section expands on the unique contribution of the study. Methodology behind the unique modelling approaches is discussed in Section 3.

**1. The study addresses a need for additional research on VaR and industry risk in an Australian context.**

With the advent of Basel II, understanding of the different market and credit VaR approaches is receiving significantly more attention. The literature survey has shown that there are very few VaR (and even fewer CVaR) studies in an Australian context, particularly as regards the topic of industry risk. The few notable studies that have been undertaken in Australia have either been on international portfolios, or focussing on different aspects to this study. Some examples are Cassidy & Gizycki (1997) who look at market risk backtesting techniques, Thomas, Allen & Morkel-Kingsbury (1999) who provide a Markov chain model for the term structure and credit risk spreads of bond process (using US data), McAleer & da Veiga (2004) who look at spillover effects (using international portfolios) and Carrett (2004) who looks at fixed interest modelling using Transition Matrices. None of these studies focus on sectoral VaR or CVaR.

Internationally, the vast majority of VaR studies have centred around individual asset or overall portfolio VaR as opposed to a sectoral approach.

This study will provide a greater understanding of the selected equity and ratings based modelling approaches, as well as industry risk, in an Australian context.

2. **The approaches discussed in the study can be used to assist banks with several facets of risk management.**

Whilst the Basel Accord and capital allocation is the primary driver behind the increased focus on credit risk modelling, it should also be noted that banks use risk measurements for a number of other risk management applications. This includes aspects such as capital allocation, formulation of sector lending policies, setting risk concentration limits, making lending decisions, reporting and monitoring requirements, pricing, and allocating lending discretions to loan officers.

The writer is aware of these practices through his experience in working in financial institutions, and these varied rating applications are also confirmed by the Australian Prudential Regulation Authority "APRA" (McDonald & Eastwood, 2000, p.p.23-24) in a survey of Australian banks.

Measurements of the above factors may be independent of any risk measurement used for capital allocation. For example, a lending officer could be given higher lending authority for a lower risk industry than for a higher risk industry, or the Bank could have more stringent lending policies surrounding higher risk industries. Greater understanding of industry risk can assist with these aspects of risk management, in addition to capital allocation. Hogan et al. (2004, p.28) note that the "measurement and management of bank risks are seen as fundamental to bank management" and that "bank risk management is increasingly sophisticated and technology dependant". The importance of development in credit modelling, even if not specifically for regulatory purposes, is recognised by APRA (1999, p.1) who is of the view that "the development and use of portfolio credit risk models within the banking industry, even if not formally incorporated into the regulatory framework at this time offers important benefits for banks and their supervisors and should not be ignored".

3. **The study derives specific industry risk measurement indices, using VaR approaches, providing a more cost effective and less modelling intensive approach to existing methods predominantly used in Australia.**

Measurement of industry risk has traditionally focussed around detailed investigations into all of the industry components such as regulatory, technological, and competitive environments, from which an industry risk will be ranked on a scale such as high medium or low. This approach requires intensive research into industry components and also does not provide a specific measurement from which to calculate loss potential. In addition, these components will generally result in a common industry ranking for both market and credit risk, whereas in reality, the risks for market and credit could be quite different. An alternate approach is the one used by CreditPortfolioView which uses multiple regression of macroeconomic factors to obtain an industry index, which is then incorporated into a Transition Matrix. These traditional approaches to measurement of industry risk are not popular in Australia as noted by APRA (1999, p.4) in their statement "Currently none of the Australian banks favours a credit risk modelling approach conditioned on the state of the economy. Apart from the additional modelling complexity involved, the banks express concern that errors in forecasting economic turning points could lead, in particular, to a shortfall in desired capital coverage just as the economy turns sharply downwards".

Whilst there is allowance within some equity based models (Moody's KMV) for the calculation of sector indices, access to these requires subscription which, as noted by Bharath and Shumway (2004, p.15), can be "prohibitively expensive".

The modelling approaches to industry risk as examined in this study, and the industry indices derived in this study, not only provide a less modelling intensive and less costly approach, but importantly, also separately measure market and credit risk.

In addition, the study provides specific Australian diversified and undiversified industry indices, based on VaR methodology, which is an improvement on correlation methods currently predominantly used by banks. As noted by APRA, (Australian Prudential Regulation Authority, 1999, p.7) an "important element in banks' credit models is the way in which interrelationships among credit exposures are handled, Some banks assume, either explicitly or implicitly, average correlations across the whole or large parts of their credit portfolios. While this approach is sensitive to large single obligor exposures, it is insensitive to the build-up of industry and geographic risk concentrations. Other banks estimate credit quality correlations based on a multi-factor analysis of world equity market prices developed by KMV Corporation. While the latter approach takes into account industry and country influences...various industries/countries may be under-represented in the stock price indices used in the correlation process".

4. **The study develops a new credit model combining Equity and Transition approaches, specifically for the Australian market.**

The CreditPortfolioView approach, as discussed in the literature survey, combines a Transition Matrix approach with macroeconomic factors. The new model takes a different approach by combining the Transition Matrix method with VaR derived industry indices, using Australian data, without the need for the macroeconomic analysis not favoured by banks. We term the new model *i*Transition as it incorporates VaR industry indices (*i*) into a Transition framework.

**5. The study develops new approaches to VaR and CVaR modelling.**

The study develops unique methodology for the incorporation of CVaR and Conditional Probability of Default (CPD) into Structural and Transition models. Whilst CVaR can readily be applied to the Equity VaR approach, the study has had to develop unique methodology to incorporate a CVaR type approach which we term Conditional Probability of Default (CPD) into a Structural approach. CVaR has previously been applied to Transition Matrices (Uryasev, Andersson, Mausser, & Rosen, 2000), but the approach used is not entirely suitable for our industry ranking purposes, and hence new Transition CVaR methodology, building on existing approaches, is developed by this study.

The study also develops methodology for calculating Structural model EDF Factors without access to KMV EDF factors which are only available by subscription.

**6. Although the study is based on Australian data, it also contributes to international credit risk modelling techniques, as the methodologies have universal application.**

The derivation of the industry indices and the creation of the new model is undertaken using Australian data. The methodology used could be applied in the same way to other universal databases.

## 1.4. Problem Definition

Meeting of the objectives outlined in Section 1.2 requires the solving of specific problems and answering of specific questions, as outlined in this section. The methodology used to address the problems and questions is discussed in Section 3.

### *1.4.1. Development of Models for Existing Approaches*

Although the literature survey outlines the methodology used by each of the approaches, we do not have access to the physical models. Model development forms a very significant part of this study, with models required for each of the three approaches (Equity, Structural, Transition).

### *1.4.2. Tailoring of Models*

Models needed to be tailored to include VaR (using undiversified and diversified approaches), Industries, and CVaR, using parametric and nonparametric approaches. This includes the formulation of new methodology where there are no suitable existing approaches (for example, no existing suitable methods are identified for the application of CVaR to Structural models).

### *1.4.3. Industry Ranking*

The model needed to assign industry rankings using each of the metrics examined in the study.

### *1.4.4. Development of iTransition*

This has included formulation of methodology conditional upon the inclusion of market derived industry factors, development of the model, and comparison of outputs to unconditional modelling.

### *1.4.5. Answering of Questions*

This has required formulation and testing of hypotheses for the following:

#### *1.4.5.1. Questions on VaR*

Is there a difference in industry VaR rankings between credit and market models? Is there a difference in VaR rankings over time? Do industry rankings differ between undiversified VaR and diversified VaR?

#### *1.4.5.2. Questions on CVaR*

Is there a difference in industry CVaR rankings between credit and market models? Is there a difference in industry rankings between VaR and CVaR within each model? Is there a difference in CVaR rankings over time? Do industry rankings differ between parametric CVaR and nonparametric CVaR?

### *1.4.6. Identification of Key Limitations of the Models*

Limitations identified through the literature survey and data collection process are examined in Section 2.4.5 and 3.3.

## 1.5. Publications and Conferences.

Three working papers have been produced from this study and submitted to various international and local conferences and journals for presentation and publication.

The papers consist of one each on Equity market risk, Structural credit risk modelling and its interaction with market risk, and Transition credit risk modelling and its interaction with market risk.

The abstracts for each of these papers are contained in Appendix 7.

## 1.6. Summary

VaR modelling techniques have gained a great deal of momentum through the Basel Accords. Market VaR methodology became very important to banks with the Basel I requirement that it be calculated on a daily basis. Credit modelling has been spurred by Basel II, which allows banks with approved sophisticated modelling to use internal models to calculate capital adequacy. This significantly benefits banks who are able to demonstrate a reduced capital requirement.

The management of sectoral concentration is a critical component of credit risk management, as over concentration of credit in sectors can be a significant contributor to difficulties experienced by banks. A study by APRA has found that Australian banks do not favour modelling conditioned on the state of the economy due to modelling intensity and potential forecasting errors, and this study will therefore look to developing approaches which allow the modelling of industry risk without the need for macroeconomic risk.

The study will examine market and credit VaR and CVaR in Australia from an industry perspective using a set of Australian industries. VaR and CVaR are to be compared between these industries over time, and a variety of metrics are to be used including diversified and undiversified VaR, as well as parametric and nonparametric CVaR methods. There has been no prior investigation of industry based VaR metrics in Australia to the author's knowledge.

Prior studies have shown a wide range of outcomes when comparing VaR results across models. Rather than focus on specific VaR outcomes, this study will focus on *relative* industry risk.

The study is anticipated to provide a number of benefits. It addresses a need for additional research on VaR, CVaR and industry risk in Australia. The approaches discussed in the study can assist banks in several facets of risk management, such as capital allocation, managing sector risk concentration, setting credit policies, pricing, and allocating lending discretions to officers according to industry. Specific industry risk measurement indices to be developed by the study using VaR approaches could provide a more cost effective and less modelling intensive approach to existing methods predominantly used in Australia.

The contribution of this study is original in several aspects. New insight is to be provided into VaR and CVaR, and the association between credit and market risk. The study will develop a new model combining market and credit approaches. Unique VaR and CVaR modelling methodologies are to be formulated, which will have universal application.

# 2. LITERATURE SURVEY

## 2.1. Outline

The literature survey includes four key components.

Firstly, given that Basel II is a key driver of the current focus on risk modelling, the key aspects of Basel II are examined.

Secondly, the Australian environment is considered. This study is specific to Australia, which requires an examination of the make up of the Australian equity and credit environment.

The third component is market VaR. The study examines key approaches to the measurement of Equity VaR. Following an initial literature survey, the study selected the variance-covariance approach for further study, however the literature survey also incorporates related approaches, concepts and theories.

Finally, key credit modelling approaches are identified and discussed. In addition to the two credit modelling approaches selected for further study (Structural and Transition), other related models, concepts and theories are discussed.

## 2.2. Basel II

### *2.2.1. Introduction*

The groundbreaking 1988 Basel Capital Accord (Basel I), originally signed by the Group of Ten (G10), but since largely adopted by over 100 countries, requires Authorised Deposit Taking Institutions (for simplicity, all forthwith referred to as "banks" in this study) to hold sufficient capital to provide a cushion against unexpected losses. Value at Risk (VaR) is a procedure designed to forecast the maximum expected loss over a target horizon, given a (statistical) confidence limit. Initially, the Basel Accord stipulated a standardized approach which all institutions were required to adopt in calculating the capital required for market and credit risk. This approach suffered from several deficiencies, the most notable of which were its conservatism (or lost opportunities) and its failure to reward institutions with superior risk management expertise.

Following much industry criticism, the Basel Accord was amended in April 1995. Basel II allows institutions to use internal models to determine their VaR and the required capital charges. However, institutions wishing to use their own models are required to have the internal models evaluated by the regulators using a back-testing procedure. The Basel Accord was adopted by the Australian government in 1988, with the Australian Prudential Regulatory Authority (APRA) as the national regulator of financial markets. Unless otherwise referenced, material regarding Basel II in this study has been sourced and summarised from the Basel II working document (Bank for International Settlements, 2004). The framework provides different options for determining capital requirements. The standardised approach is based on ratings from eligible external rating agencies. The internal ratings based (IRB) approach is based on the banks' internal ratings models, and is only available to banks with highly sophisticated risk management processes.

### *2.2.2. The 3 Pillars*

The Basel II framework consists of 3 Pillars.

#### *2.2.2.1. Pillar 1: Capital Requirements*

This Pillar prescribes minimum capital requirements for credit, market and operational risk. The total capital ratio must be no lower than 8% of risk weighted assets. Whilst this ratio is the same as the Basel I Accord, the difference is the revised options for calculating risk weighted assets.

Capital is divided into Tier 1 and Tier 2 Capital. Tier 2 capital may not exceed Tier 1 capital.

Further discussion on capital definitions and the risk weighting of assets is contained in sections 2.2.3 and 2.2.5.

#### *2.2.2.2. Pillar 2: Supervisory Review*

Supervisors are required to ensure that banks comply with the capital adequacy requirements and have adequate processes and systems in place in place determining capital requirements. The supervisor in Australia, APRA, has regular consultation with bank management, conducts inspections of systems & compliance, and ensures systems are used in practice. APRA also reviews statistical returns received from banks and external auditor reports.

#### *2.2.2.3. Pillar 3: Market Discipline:*

Banks will be required to disclose more detail about their risks & systems.

### 2.2.3. *Capital Definitions*

Capital is split into Tier 1 Capital and Tier 2 Capital.

Tier 1 Capital includes paid up ordinary shares, paid up non cumulative irredeemable preference shares, retained profits, reserves (other than asset realisation reserves), and qualifying innovative equity instruments and certain capital instruments issued under a special purpose vehicle.

Upper Tier 2 Capital includes asset revaluation reserves, general provisions for doubtful debts, and hybrid debt/equity issues.

Lower Tier 2 Capital includes subordinated term debt with an original maturity of at least 2 years.

### 2.2.4. *Categories of Risk*

Total capital requirements will consist of the sum of capital required for the following risks:

#### *2.2.4.1. Market Risk*

Market risk arises from factors that affect the whole market. It is the risk of loss from adverse movement in market factors such as interest rates, exchange rates, commodities and equities.

The capital charge for market risk can be calculated using the Regulator's standard method or internal model's approach. Using internal models can be advantageous as the standard approach is likely to generate more conservative (higher) values for the capital charge (Hogan et al., 2004, p.43). Market risk is calculated on a

Value at Risk (VaR) approach. Market VaR approaches are discussed in greater detail in section 2.4.

#### *2.2.4.2. Operational Risk*

This did not form part of Basel I. Operational Risk covers processing, transactional and procedural risks. Banks may use either the standardised or IRB approach. The standardised approach involves segmenting business along standard business lines and then applying a factor (beta) for each line. The beta is determined by the regulator & is a function of the overall industry.

The Internal models approach is only available to Bank's with highly sophisticated systems. The Bank calculates a measure for operational risk based on past experience & projections.

#### *2.2.4.3. Credit Risk*

This is the risk of loss from default on a credit obligation. As credit risk is a key aspect of this study, the remainder of this chapter is devoted to Basel II treatment of this risk.

### *2.2.5. Credit Risk Capital Requirements*

Basel II classifies exposures as a) corporate, b) sovereign, c) bank, d) retail, or e) equity. This discussion only applies to a) corporate.

Banks may adopt one of 3 approaches, including the standardised approach, IRB foundation level approach, and IRB advanced level approach.

#### 2.2.5.1. *Credit Risk Standardised Approach*

Under the standardised approach, there are five risk weighted categories (0%, 20%, 50%, 100% and 150%).

These weightings apply to both on balance assets (simple calculation) and off balance sheet assets (more complex calculation – convert to on balance sheet value using conversion factors supplied by regulator).

The standardised approach relies on external ratings. A single consistent approach is required, i.e. a bank must use external ratings for all exposures, or treat all exposures as unrated. Rating agencies must be approved by national supervisors in accordance with criteria laid down in the Accord. Risk weightings of Corporates are as follows:

Table 2-1 *Basel II Corporate Risk Weights*

The percentages show the risk weighting that must be applied to the assets for the purpose of calculating capital allocation. These weightings do not include exposures to small business, which are categorised as retail and qualify for 75% weighting and must meet certain criteria, such as being < €1m and being < 0.2% of the overall retail portfolio.

| Credit assessment | AAA to AA- | A+ to A- | BBB+ to BB- | Below BB- | Unrated |
|---|---|---|---|---|---|
| Risk Weight | 20% | 50% | 100% | 150% | 100% |

(Bank for International Settlements, 2004, p.19)

Past due loans are weighted at 100 - 150% depending on specific provisions. 150% is used when specific provisions are <20% of the outstanding loan. 100% is used when specific provisions are no less than 50% of the outstanding loan (but can be reduced to 50% at supervisor's discretion).

Lending fully secured by residential property is weighted at 35%, and secured by commercial property 100%.

Off balance sheet exposures are converted into credit exposure equivalents through the application conversion factors (CCF) which range from 0 – 100% depending on maturity and other factors specified in the Accord.

Ratings of approved external credit assessment institutions (ECAI) must be mapped to the standardised risk weighting framework by supervisors.

### *2.2.5.2. IRB Approach*

Banks using an IRB approach must use it across the entire banking group. The Accord does allow for a phased rollout across asset classes/business units, subject to an agreed rollout plan with the supervisor.

For corporate, sovereign, and bank exposures, data under the advanced approach must cover one business cycle but must in any case be at least 7 years (Bank for International Settlements, 2004, p.100 ).

The capital requirement (K) is calculated as a function of:

P Probability of default (also often referred to as PD)

LGD Loss given default

EA Exposure at default

M Effective maturity (in some cases)

This approach has two levels – the foundation approach and the advanced approach. Under the foundation approach, banks generally provide their own P and rely on supervisory estimates for other components. LGD under the foundation approach is 45% for corporates (75% if subordinated). Under the advanced approach, banks generally provide more of their own estimates of P, LGD, EA, M, subject to meeting certain standards.

Calculation of Risk Weighted Assets (RWA) is as follows:

$$RWA = K(PD,LGD,M) \times 12.5 \times EA \qquad (2\text{-}1)$$

(12.5 is simply the reciprocal of the 8% capital requirement).

Assume $K = 4\%$, $EA = \$10m$.

$(4\% * 12.5) \times 10m = 5m.$

There are a number of additional special parameters stipulated by Basel II. We mention here the key ones relevant to the measurement of corporate credit risk. This includes the definition of Small & Medium Enterprises (SME's), which are those entities where the reported sales are less then €50m. In these cases a weighting factor of between 0 (50,000,000 sales) and 0.04 (5,000,000 sales or less) is applied. Another special parameter is the requirement for at least 5 years historical data. There is also a transition period. Up until 2009, there will be a capital floor in place under the IRB approach, based on application of the 1988 Accord multiplied by an adjustment factor. In 2006 the adjustment factor was 95%, in 2007 90% and in 2008 80%.

### *2.2.6. Implementation in Australia*

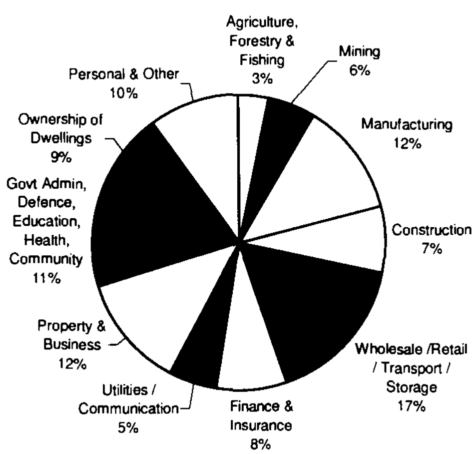
Basel II allows for a staggered approach, with all but the most sophisticated approaches available from year end 2006 and the more sophisticated approaches available from year end 2007.

APRA (2004a; 2004b) does not favour the 'staggered' approach whereby different approaches are adopted within different timeframes and has decided on a common implementation date of year end 2007 for all approaches, which allows an extra year for systems changes to be made. Banks will be required to meet the new capital requirements from 1 January 2008.

## 2.3. The Australian Market

### *2.3.1. Sector Composition*

The Australian GDP comprises the following sectors:




| | | |
|---|---|---|
| Agriculture, Forestry & Fishing | 26.9 | 3.2% |
| Mining | 46.3 | 5.5% |
| Manufacturing | 104.2 | 12.4% |
| Construction | 61.9 | 7.4% |
| Wholesale Trade | 43.2 | 5.1% |
| Retail Trade | 52.5 | 6.2% |
| Transport & Storage | 41.2 | 4.9% |
| Finance & Insurance | 64.5 | 7.7% |
| Electricity, Gas & Water Supply | 19.9 | 2.4% |
| Accommodation, Cafes & Restaur | 19.9 | 2.4% |
| Communication Services | 25.2 | 3.0% |
| Property & Business Services | 104.6 | 12.4% |
| Government Administration & Def | 35.1 | 4.2% |
| Education | 39.2 | 4.7% |
| Health & Community Services | 55.6 | 6.6% |
| Cultural & Recreational Services | 11.6 | 1.4% |
| Personal & Other Services | 16.5 | 2.0% |
| Ownership of Dwellings | 72.5 | 8.6% |
| | 840.8 | 100.0% |

*Figure 2-1.* Australian Sector Composition ($bn)

Data obtained from Australian Bureau of Statistics (2006, p63)

The composition of GDP has changed over the last century. In 1900-01, Agriculture, Forestry and Fishing contributed 19% to GDP, with Manufacturing and Mining 10 – 12 % each. In 1950-51, Agriculture was 30%, and Mining 3%. (Australian Bureau of Statistics, 2003 pp.1-3) As with most developed economies, GDP is now characterised by a large Services sector, with GDP growth one of the highest among developed countries (Australian Government Department of Foreign Affairs & Trade, 2002, Appendix 1, pp.134-135).

Small businesses (those employing less than 20 people, or less than 100 people in a manufacturing business) are estimated at 1.2m in number, representing 97% of all private sector businesses (Australian Bureau of Statistics, 2002, p.2).

There has been significant growth in the Australian Equities Market. In 1992, the domestic market capitalisation was $198 billion, and has since grown to $1.4 trillion (Australian Stock Exchange, 2006a, p.1).

The table below shows the sector and sub-sector classifications used by the Australian Stock Exchange (ASX).

Table 2-2 *Sector Breakdown*

Sectors are based on the Global Industry Classification Standard (GICS) which is a joint Standard & Poor's / Morgan Stanley Capital International Product aimed at standardising global industry classifications (Australian Stock Exchange, 2006b, p.1). Broad GICS sector categories are shown in column 1, with the detailed sectors shown in Column 2.

| **Sector** | **Sub sectors** |
|---|---|
| Energy | Oil & Gas, Energy Equipment & Services |
| Materials | Metals & Mining, Construction Materials, Chemicals, Paper & Forest Products, Containers & Packaging |
| Industrials | Transportation, Capital Goods, Commercial Services & Supplies |
| Consumer Discretionary | Media, Hotels Restaurants & Leisure, Retailing, Consumer Durables & Apparel, Automobile & Components |
| Consumer Staples | Food Beverage & Tobacco, Food & Staples Retailing, Household & Personal Products |
| Health Care | Equipment & Services, Pharmaceuticals & Biotechnology |
| Financials | Banks, Real Estate, Diversified Financials, Insurance |
| Information Technology | Software & Services, Technology & Equipment, Semiconductors & Semiconductor Equipment |
| Telecommunications Services | Diversified, Wireless |
| Utilities | Gas, Electric, Multi, Water |

(Australian Stock Exchange, 2006b, p.1)

The S&P/ASX 200 is recognised as the investable benchmark for the Australian equity market and comprises 200 stocks selected by the S&P Australian Index

Committee and represents approximately 90% of the total market capitalisation of the Australian Market (Standard & Poor's, 2006a, p.1).

The All Ordinaries index (All Ords) is considered to be Australia's market indicator, representing the 500 largest companies listed on the stock exchange (Standard & Poor's, 2006a, p.1), and is the index used in this paper. Table 2-3 provides a breakdown of the market capitalisation of All Ords companies.

Table 2-3 *All Ords Market Capitalisation ($000)*

Column 1 shows the detailed Sector breakdown of All Ords companies. Market Capitalisation is at June 2006. Data has been obtained from DataStream and aligned to GICS codes.

| **Industry** | **Market capitalisation** | **% of Total** |
|---|---|---|
| Automobiles & Components | 940 | 0.08% |
| Banks | 238,684 | 19.45% |
| Capital Goods | 29,655 | 2.42% |
| Chemicals | 11,481 | 0.94% |
| Commercial Services & Supplies | 30,875 | 2.52% |
| Containers & Packaging | 6,134 | 0.50% |
| Construction Materials | 26,321 | 2.15% |
| Consumer Durables & Apparel | 4,301 | 0.35% |
| Diversified Consumer Services | 1,132 | 0.09% |
| Diversified Financials | 54,062 | 4.41% |
| Energy | 80,045 | 6.52% |
| Food & Staples Retailing | 44,120 | 3.60% |
| Food Beverage & Tobacco | 29,569 | 2.41% |
| Healthcare Equipment & Services | 20,550 | 1.67% |
| Hotels Restaurants & Leisure | 20,165 | 1.64% |
| Insurance | 60,010 | 4.89% |
| Media | 33,510 | 2.73% |
| Metals & Mining | 210,929 | 17.19% |
| Paper & Forest Products | 5,373 | 0.44% |
| Pharmaceuticals & Biotechnology | 18,659 | 1.52% |
| Real Estate | 128,718 | 10.49% |
| Retailing | 10,839 | 0.88% |
| Software & Services | 8,845 | 0.72% |
| Technology Hardware & Equipment | 1,944 | 0.16% |
| Telecommunication Services | 91,567 | 7.46% |
| Transportation | 38,521 | 3.14% |
| Utilities | 20,082 | 1.64% |
| | 1,227,031 | |

Source: Datastream

### 2.3.2. *Australian Banking Market*

As shown in Figure 2-2, the major 4 banks hold 72% of outstanding loans and advances. These banks are Westpac, ANZ, Commonwealth Bank of Australia and National Australia Bank. There are only 3 other banks who hold a greater than 2% market share. These are BankWest, Suncorp Metway, and St George. As at July 2006, total outstanding loans and advances were just over $1 trillion. The largest slice of this ($647 billion) was personal lending. Commercial loans were $404 billion, and loans to Government $12 billion.

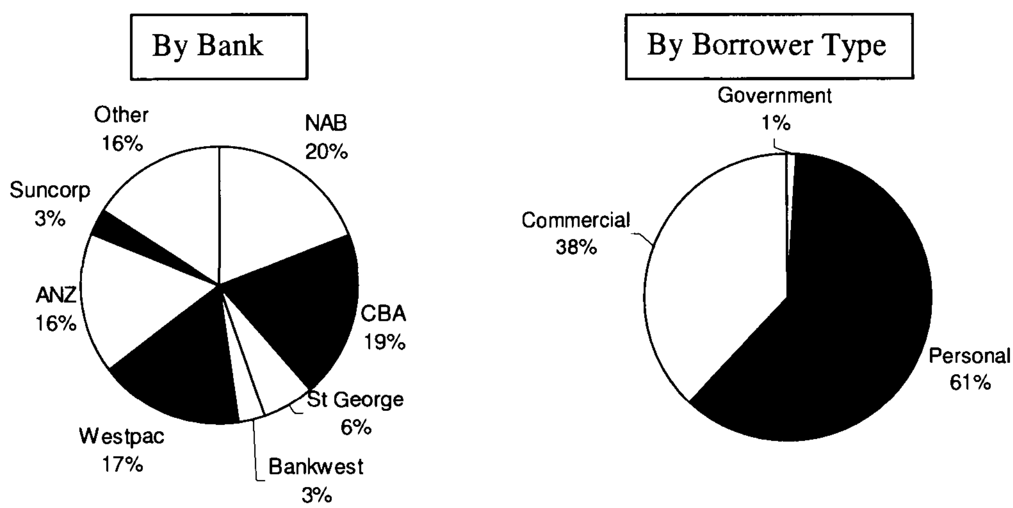



*Figure 2-2.* Total Outstanding Loans

Source Bank Data: (APRA, July 2006)
Source Borrower Type Data: (Reserve Bank of Australia, July 2006)

The focus of this study is the Commercial sector, which is the subject of the following graphs. During the 12 months to March 2006, $231 billion in new credit approvals was made to businesses. $2.3 bn was in leasing, $88.7bn in revolving credit facilities, and the balance of $140bn was in various categories of term lending, as illustrated in the following graph.

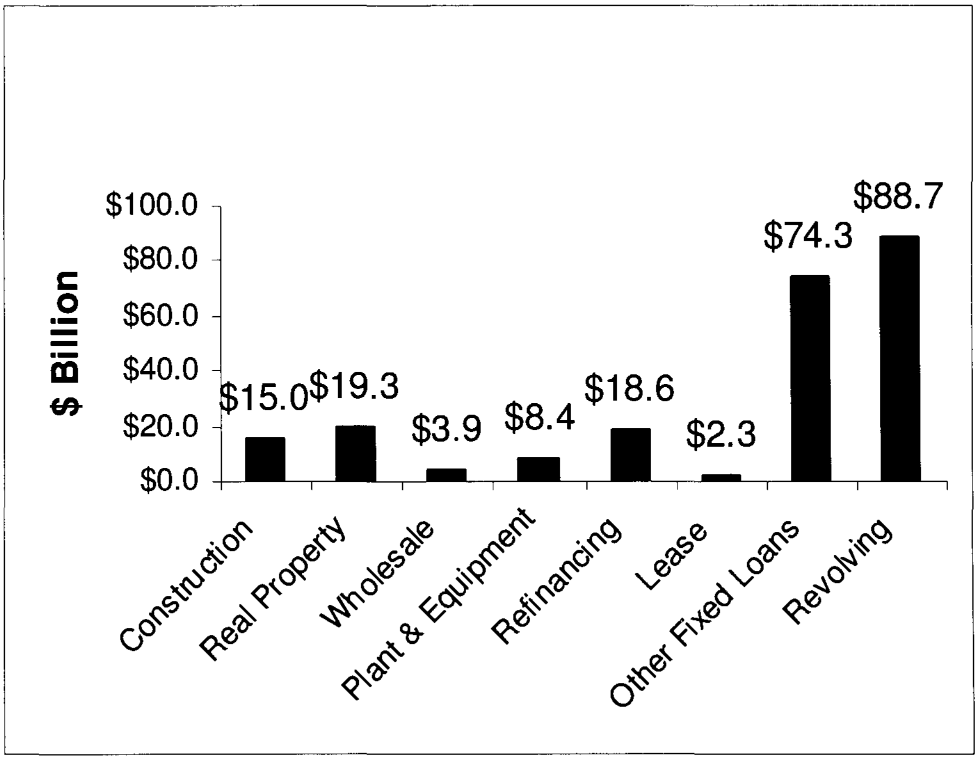



*Figure 2-3.* New Credit Approvals by Purpose
Data Source: Reserve Bank of Australia (March 2006)

Table 2-4 shows loan size by dollar value.

Table 2-4 *Credit Approvals by Size*

The table shows, by value, loans >$2m represented 75% of all new lending over the 12 months to March 2006. Reserve Bank statistics do not provide a breakdown of number of loans in each category. However, it is a well known feature of Australian banks that the vast majority of loans by number are in the smaller loan categories (97% as per Section 2.3.1).

| Loan size | $-bn | % |
|---|---|---|
| < $100,000 | $7.2 | 3.1% |
| $100,000 -< $500,000 | $20.9 | 9.1% |
| $500,000 - < $2,000,000 | $30.0 | 13.0% |
| > $2,000,000 | $172.4 | 74.8% |
| | $230.5 | 100.0% |

Data Source: Reserve Bank of Australia (March 2006)

## 2.4. Value at Risk

### *2.4.1. Introduction*

The VaR approach to risk measurement has gained a great deal of momentum in recent years, following the launch of the RiskMetrics Technical document by J.P. Morgan in 1994 and subsequent updates (J.P. Morgan & Reuters, 1996). The definition and methodology is described and summarised in several references (for example, Choudhry, 2004; GloriaMundi.Org, n.d.; Harper, 2004a, p.2-3). VaR calculates maximum expected losses over a given time period at a given tolerance level.

There are 3 methods of calculating VaR. TheVariance-Covariance method estimates VaR on assumption of a normal distribution. The Historical method groups historical losses in categories from best to worse and calculates VaR on the assumption of history repeating itself. Monte Carlo Simulation simulates multiple random scenarios.

In a banking environment, VaR is primarily used to measure market risk. However, the VaR concept has also been included in credit risk measurement, notably the J.P. Morgan Creditmetrics model (Gupton, Finger, & Bhatia, 1997) which is discussed in Section 2.5.4.2.

### *2.4.2. Variance-Covariance Approach.*

This approach assumes returns are normally distributed. The method is well documented by Choudhry (2004, p.p.667-674, 804-808), and unless otherwise referenced, this section follows his approach.

To obtain VaR for a single asset X, all that needs to be calculated is the mean and standard deviation. Using standard distribution tables (Statsoft Inc., 2003), and given the normal curve assumption, we automatically know where the worst 1% and 5% lie on the curve:

95% confidence = -1.645 x $\sigma_x$

99% confidence = -2.330 x $\sigma_x$

*Example:*

If Standard Deviation = 12.4%

VAR at 95% confidence = 12.4% x -1.645 = 0.2040

VAR at 99% confidence = 12.4% x 2.330 = 0.2889

If asset x = \$1.28m then VaR \$ at 95% confidence = \$ 0.26m. VaR at 99% confidence = 0.37m.

When calculating VaR, it is usual practice to not use actual asset figures, but the logarithm of the ratio of price relatives, obtained by using the following calculation:

$$\ln\left(\frac{P_t}{P_{t-1}}\right) \qquad (2\text{-}2)$$

i.e. the logarithm of the ratio between today's price and the previous price. This is the method used by RiskMetrics (J.P. Morgan & Reuters, 1996, p.p.45-48), who introduced and popularised VaR.

The normal distribution assumption that is generally assumed to apply to financial time series observations implies extreme negative values which are not observed in practice with share prices. Thus the lognormal distribution is considered more suitable for measuring share prices, removing the probability of negative prices

(Choudhry, 2004, p.806). The lognormal distribution is bounded by zero on the low side. Investors normally compare asset performance in terms of returns, and it is generally simplest to assume these returns are normally distributed. It follows that the price is lognormally distributed, i.e. $\ln(P_t / P_{t-1})$ is normally distributed and $P_t / P_{t-1}$ is lognormally distributed (C. Alexander, 2001, p.4).

When additional assets are introduced into the portfolio, we need to account for correlations between the assets. Correlations are discussed in section 2.6.

The variance-covariance matrix is the approach used by RiskMetrics (J.P. Morgan & Reuters, 1996), and whose credit model CreditMetrics (Gupton et al., 1997) is examined later in Section 2.5.4.2.

### *2.4.3. Historical Approach:*

This approach sorts the daily returns from worst to best. At 95% confidence level, it will ascertain the lowest 5% of returns. Assume 250 observations, 5% = 12.5 observations. VAR will be the smallest of the losses experienced in the 12.5 days. At 99% confidence level, the number of observations is 2.5. (Harper, 2004, p.2-3 and Choudhry, 2004, p.679).

The problem with this approach is that the relative weightings of assets could have been changing over the historical period. To overcome this, a method called historical simulation is used (Choudhry, 2004, p.p. 679-680). Assume at the end of the period we have 58%x and 42%y, but at some previous period we had weightings 50%x and 50%y (or some other combination besides 58:42). We will re-weight all historical prices to be 58%x and 42%y.

### *2.4.4. Monte Carlo Simulation:*

This approach generates future simulated prices. We calculate portfolio volatility and correlation (as per variance-covariance approach, Section 2.6.1.). These values are used in a random number simulation to generate portfolio value changes and revalue the portfolio at each simulation. The 95th percent lowest value will be VaR at a confidence level of 95% and the 99th percent lowest value will be VaR at 99% confidence. For 50,000 simulations this will be 2,500th lowest number at 95% confidence level and 500th lowest number at 99% confidence level. (GloriaMundi.org, p.4 and Choudhry, 2004, p. 680)

### *2.4.5. Limitations of VaR:*

Despite it's popularity, VaR has been criticised as having some undesirable properties. The most notable work in this regard has been undertaken by Artzner, Delbaen, Eber, & Heath (1999; 1997), who argue that VaR is not a 'coherent' measure of risk as it does not satisfy the following mathematical properties:

i. *Subadditivity*: the VaR resulting from the combination of two portfolios should not be greater than the sum of the risks of the individual portfolios, i.e. $\rho(X+Y) \leq \rho(X)+\rho(Y)$

ii. *Translation invariance*: adding a constant (e.g. a risk free asset such as cash) to a portfolio should change risk by the same amount, i.e. $\rho(X+a)=\rho(X)+a$

iii. *Positive homogeneity:* the relative size of the position should directly influence the risk (doubling all positions will double the risk), i.e. $\rho(\lambda X)=\lambda\rho(X)$

iv. *Monotonicity:* if the outcome of one variable is less than the outcome of another variable in every instance, then the first variable should have the greater portfolio risk, i.e. if $X < Y$ in all instances then $\rho(X) < p(Y)$.

A further problem, as discussed by McKay & Keefer (1996) and Mauser and Rosen (1999) is that VaR is difficult to optimise when calculated from scenarios. It can be difficult to resolve as a function of portfolio position and can exhibit multiple local extrema, which makes it problematic to determine the optimal mix of positions and the VaR of a particular mix.

The above limitations are not found with CVaR, which we explore as an alternative to VaR in Section 2.7.

## 2.5. Credit Risk Measurement Models

### *2.5.1. Introduction*

There are various ways of measuring credit risk. These are all briefly mentioned in this introduction, and examined in greater detail in Sections 2.5.2 through to 2.5.4.

Historically the more prominent methods have included banks' internal rating methodologies, external ratings services like Moody's, Standard & Poor's (S&P) or Fitch, and Financial Statement Analysis models (which provide a rating based on the analysis of financial statements of individual borrowers, such as the Altman z score and Moody's RiskCalc).

Credit risk models which measure default probability have attained a great deal more prominence with the advent of Basel II. These include Structural models, VaR based models, and Reduced Form models

Structural models are based on option pricing methodologies and obtain information from market data. A default event is triggered by the capital structure when the value of the obligor falls below its financial obligation (such as KMV Corporation).

VaR based models provide a measurement of expected losses over a given time period at a given tolerance level as discussed in the previous chapter (such as the JP Morgan CreditMetrics model which uses a Transition Matrix, the CreditPortfolioView model which incorporates macroeconomic factors into a Transition approach, and the Credit Risk+ model which uses an insurance based modelling approach).

Reduced Form models differ from Structural models in that they make no assumption about causes of default, and use a risk neutral Transition Matrix in the determination of default probabilities.

External Credit rating models are primarily designed for portfolios with large, publicly rated corporations.

In Australia, the vast majority of borrowers are not publicly listed entities, and the writer is aware through his experience working in banks, that there is a large reliance on banks' internal rating systems, taking into account such factors as historical earnings, projected future earnings, debt equity structure, liquidity, management capability and integrity, historical account conduct, and industry factors.

Models which use both qualitative and quantitative information are referred to by Hogan et al. (2004, p.p.309-31) as "judgemental" credit analysis models as compared to "quantitative" models where no subjective information is included, and the authors note that the choice of which type of model to use "will depend on factors such as simplicity, accuracy, transparency, value-adding, the ability to customise and the need to estimate the probability of default."

Banks with internal ratings models will usually calibrate their default probabilities with the ratings of the external models.

### *2.5.2. External Ratings Services*

The most prominent of the ratings services are Standard & Poor's (S&P), Moody's & Fitch.

Table 2-5 *Mapping of Rating Agencies*

The table provides a calibration between the well known rating agencies. The definitions are based on Standard & Poor's. This calibration is important when modelling data which contains loans from different ratings services.

| S & P | Moody's | Fitch | Definition |
|---|---|---|---|
| AAA | Aaa | AAA | Best credit quality – Extremely reliable with regard to financial obligations |
| AA+ | Aa1 | AA+ | |
| AA | Aa2 | AA | Very good credit quality – Very reliable |
| AA- | Aa3 | AA- | |
| A+ | A1 | A+ | |
| A | A2 | A | More susceptible to economic conditions – still good credit quality |
| A- | A3 | A- | |
| BBB+ | Baa1 | BBB+ | |
| BBB | Baa2 | BBB | Lowest rating in investment Grade |
| BBB- | Baa3 | BBB- | |
| BB+ | Ba1 | BB+ | |
| BB | Ba2 | BB | Caution is necessary – Best sub-investment credit quality |
| BB- | Ba3 | BB- | |
| B+ | B1 | B+ | |
| B | B3 | B | Vulnerable to changes in economic conditions – currently showing the ability to meet its financial obligations |
| B- | Caa1 | B- | |
| CCC+ | Caa2 | CCC+ | |
| CCC | Caa3 | CCC | Currently vulnerable to non-payment – dependent on favourable economic conditions |
| CCC- | Ca | CCC- | |
| CC | C | CC | Highly vulnerable to payment default |
| C | | | Close to or already bankrupt – payment on the obligation currently continued |
| D | | | Payment default on some financial obligation has already occurred |

Source of Calibrations: BIS (cited in Saunders & Allen, 2002, p. 43)

Source of Definitions: (riskglossary.com, 2005b, p.2)

### *2.5.3. Financial Statement Analysis Models*

These models provide a rating based on the analysis of various financial statement items and ratios of individual borrowers. Examples include the z score and Moody's RiskCalc.

Edward Altman (1968 and revisited 2000) developed the z score which uses five ratios in the prediction of bankruptcy. The ratios and their weightings are 0.012(working capital / total assets), 0.014(retained earnings / total assets), 0.033(earnings before interest and taxes / total assets), 0.006(market value equity / book value of total liabilities), and 0.999(sales / total assets ratio).

Moody's KMV Company (2003, p.1) RiskCalc model provides an Estimated Default Frequency (EDF) for private firms. In Australia, the research database is calibrated using 93,701 financial statements and 2,519 defaults from 26,636 Australian companies. EDF is calculated from 11 financial measures, including size (assets), liquidity (current ratio; cash /assets), profitability (retained earnings / assets; EBITDA / interest expense; NI extraordinary items / sales; previous year NI / Sales), activity: (inventory / sales), and gearing (tangible net worth / tangible assets).

### *2.5.4. Credit Risk Default Probability Models.*

This section discusses the five prominent credit risk measurement models, including Moody's KMV Public Firm Model, CreditMetrics (JP Morgan), CreditPortfolioView (McKinsey), Credit Risk + (Credit Suisse Financial Products – CSFP), and Reduced Form Models.

### *2.5.4.1. Structural Model*

KMV Credit Monitor (Crosbie & Bohn, 2003) provides an estimated default frequency (EDF) for individual assets, using market information. It is based on a modification of Merton's Asset Value Model.

The Merton / KMV approach as described in Crosbie & Bohn (2003) and Saunders & Allen (2002, p.p. 49-66) is based on the work of Black and Scholes in 1973. The model assumes that the firm has one single debt issue and one single equity issue. The debt (D) consists of a zero coupon bond that matures at time (T). Zero coupon bonds are bonds that do not pay interest during the life of the bonds. Instead, investors buy zero coupon bonds at a deep discount from their face value, which is the amount a bond will be worth when it "matures" or comes due.

The initial position (asset value) of the firm is;

$$A0 = E0 + D0. \qquad (2\text{-}3)$$

The value of the firm:

$$V_0 = A_0. \qquad (2\text{-}4)$$

At T, the firm pays off the bond and the remaining equity is paid to the shareholders.

The firm defaults if the debt obligation exceeds the asset value of the firm at T. In this case the bondholders take ownership of the firm and the shareholders get nothing (due to limited liability of shareholders the amount will not be negative).

The amount paid to bondholders = b.

Equity at T (remaining value payable to the shareholders) is as follows:

$$ET = VT - b \qquad (2\text{-}5)$$

Where the debt value is greater than the asset value, then $E_T = 0$.

Thus the value of a firms stock at debt maturity:

$$ET = max(AT - b, 0) \qquad (2\text{-}6)$$

This is the same as the payoff of a call option on the firm's value with strike price b. A call option is an option contract that gives the holder the right to buy a certain quantity (usually 100 shares) of an underlying security from the writer of the option, at a specified price (the strike price) up to a specified date (the expiration date).

If, at T, assets exceed loans, the owners will exercise the option to repay the loans and keep the residual as profit. If loans exceed assets, then the option will expire unexercised and the owners (who have limited liability) default. The call option is in the money where $AT - b > 0$, and out the money where $AT-b < 0$.

Merton uses the assumption that asset values are log normally distributed.

Under the KMV model, Probability of Default PD is a function of the distance to default DD (number of standard deviations between the value of the firm and the debt) determined by using the market value of assets (A), less the amount of debt (b) divided by the volatility of assets $\sigma$.

$$\frac{A-b}{\sigma A} \qquad (2\text{-}7)$$

Assume :

Borrowings (b) = \$80m

$\sigma A$ (1 std deviation) =\$10m

Market Value of Assets (A) = \$100m

Then:

$$\text{DD} = \frac{\$100m - 80m}{10m}$$

$$= \text{2 standard deviations.}$$

Probability of default (PD) could be determined using the normal distribution. If the firm's assets fall below \$80m within 1 year, then the firm is in default. In this case it is two standard deviations. We know there is a 95% probability that assets will vary between 1 and two standard deviations. There is a 2.5% probability that they will fall by more than 2 standard deviations.

KMV find that the normal distribution approach followed by Merton results in PD values much smaller than defaults observed in practice. KMV has a large worldwide database from which to provide empirically based EDFs. For example, KMV finds that historical data shows that firms with a DD of 4 have an average default rate of approximately 1% and therefore assign an EDF of 1% to firms with this DD. By comparison, the normal distribution approach yields a PD of almost 0 for this DD. (Crosbie & Bohn, 2003, p.18).

In KMV, b is taken as the value of all short-term liabilities (one year and under) plus half the book value of all long term debt outstanding. T is usually set as 1 year.

Thus the KMV model consists of 3 steps. Firstly, estimate market value and volatility of firms assets. Secondly, calculate distance to default. Thirdly, match distance to default to an empirically obtained EDF.

The KMV model is based around the Merton approach, and to understand some of the more intricate details of estimating default probabilities, we examine this approach more closely.

Equity and the market value of the firm' assets are related as follows:

$$E = VN(d_1) - e^{-rT} FN(d_2) \qquad (2\text{-}8)$$

$E$ = market value of firms equity

$F$ = face value of firm's debt

$r$ = instantaneous risk free rate

$N$ = cumulative standard normal distribution function

$$d_1 = \frac{\ln(V/F) + r(+0.5\sigma_v^2)}{\sigma v\sqrt{T}} \qquad (2\text{-}9)$$

$$d_2 = d_1 - \sigma_v \sqrt{T} \qquad (2\text{-}10)$$

Volatility and equity are related under the Merton model as follows:

$$\sigma_E = \left(\frac{V}{E}\right) N(d_1)\sigma_V \qquad (2\text{-}11)$$

Bharath and Shumway (2004, p6-7) describe a 6 step process to calculating probability of default:

1. Estimate $\sigma_E$ from historical data or from option implied volatility data.

2. Choose a forecasting horizon (commonly 1 year) and a measure of the face value of the firm's debt (commonly the book value of a firm's liabilities).

3. Obtain values for the risk free rate and market equity of the firm

4. Simultaneously solve equations (2.8) and (2.11). Due to movement in market leverage, KMV do not solve this equation numerically, but instead implement an iterative procedure. An initial asset value is estimated, which Bharath and Shumway (2004, p.7) propose as

$$\sigma_V = \sigma_E \left( \frac{E}{E+F} \right) \tag{2-12}$$

This is applied to equation (2.8) to estimate the market value of assets every day. The daily log return is calculated and new asset values estimated. This process is repeated until asset returns converge.

5. Calculate distance to default as

$$DD = \frac{\ln(V/F) + (\mu - 0.5_v^2)T}{\sigma_V \sqrt{T}} \tag{2-13}$$

$\mu$ is an estimate of the annual return (drift) of the firm's assets. This can be calculated as the mean of the change in $lnV$ (Vassalou & Xing, 2002).

6. Calculate probability of default as

$$PD = N(-DD) \tag{2-14}$$

Table 2-6 *The Mapping of S&P Credit Ratings to KMV EDF Values*

KMV provide the following mapping of Estimated Default Frequency (EDF) to S&P Credit Ratings. The EDF values are estimated by KMV from their lage worldwide database. KMV EDF ranges from 0.00% to 20%. By using the table in conjunction with Table 2-5, EDF values can also be mapped to the ratings of Moody's and Fitch.

| S&P Rating | KMV EDF Value (%) |
|---|---|
| AAA | (0.00, 0.02) |
| AA+ | (0.02, 0.03) |
| AA | (0.03, 0.04) |
| AA- | (0.04, 0.05) |
| A+ | (0.05, 0.07) |
| A | (0.07, 0.09) |
| A- | (0.09, 0.14) |
| BBB+ | (0.14, 0.21) |
| BBB | (0.21, 0.31) |
| BBB- | (0.31, 0.52) |
| BB+ | (0.52, 0.86) |
| BB | (0.86, 1.43) |
| BB- | (1.43, 2.03) |
| B+ | (2.03, 2.88) |
| B | (2.88, 4.09) |
| B- | (4.09, 6.94) |
| CCC+ | (6.94, 11.78) |
| CCC | (11.78, 14) |
| CCC- | (14, 16.70) |
| CC | (16.7, 17.00) |
| C | (17.00, 18.25) |
| D | (18.25, 20) |

Source: KMV Credit Monitor as cited in Lopez (2002, p.25)

#### *2.5.4.2. CreditMetrics (Transition)*

CreditMetrics is a product of the RiskMetrics Group, which was formally part of JP Morgan.

#### *2.5.4.2.1. Transition table*

This approach incorporates a Transition table, as illustrated in Table 2-7.

Table 2-7 *One Year Transition Matrix %*

The Transition table shows the likelihood of a borrower moving from one credit grade to another. The table is based on historical data collected from external rating agencies. For example, we can see from the matrix below, that the one-year probability of a borrower's credit rating moving from A to BBB is 5.52%. The matrix is provided by CreditMetrics based on an S&P table which includes a 'not rated' category. CreditMetrics exclude this category and adjust all remaining probabilities in the row on a pro-rata basis.

| Initial | Rating at year end (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rating | AAA | AA | A | BBB | BB | B | CCC | Default |
| AAA | 90.81 | 8.33 | 0.68 | 0.06 | 0.12 | 0 | 0 | 0 |
| AA | 0.70 | 90.65 | 7.79 | 0.64 | 0.06 | 0.14 | 0.02 | 0 |
| A | 0.09 | 2.27 | 91.05 | 5.52 | 0.74 | 0.26 | 0.01 | 0.06 |
| BBB | 0.02 | 0.33 | 5.95 | 86.93 | 5.3 | 1.17 | 0.12 | 0.18 |
| BB | 0.03 | 0.14 | 0.67 | 7.73 | 80.53 | 8.84 | 1.00 | 1.06 |
| B | 0 | 0.11 | 0.24 | 0.43 | 6.48 | 83.46 | 4.07 | 5.2 |
| CCC | 0.22 | 0 | 0.22 | 1.3 | 2.38 | 11.24 | 64.86 | 19.79 |

Source: CreditMetrics (Gupton et al., 1997, p. 20)

This following VaR calculation example is based on an example by CreditMetrics (Gupton et al., 1997, p.p.27-29) and also presented and discussed by Saunders & Allen (2002, p.p.87-92), and Allen (2002, p.p.17-20).

Consider a 5 year BBB rated loan of $100 at an annual interest rate of 6%. CreditMetrics proposes two steps. Firstly, obtain the forward zero curves for each category . Secondly, using the zero curves, calculate the market value (V) of the loan at the one year risk horizon. Assuming the following zero curves have been given to us:

Table 2-8 *Transition Matrix Example: Forward Zero Curves*

This table is based on an example provided by CreditMetrics. These are the risk free rates, so called forward zero rates for each rating category, on US Treasury bonds, expected to exist in a year's time.

| Category | Year 1 | Year 2 | Year 3 | Year 4 |
|---|---|---|---|---|
| AAA | 3.60 | 4.17 | 4.73 | 5.12 |
| AA | 3.65 | 4.22 | 4.78 | 5.17 |
| A | 3.72 | 4.32 | 4.93 | 4.32 |
| BBB | 4.10 | 4.67 | 5.25 | 5.63 |
| BB | 5.55 | 6.02 | 6.78 | 7.27 |
| B | 6.05 | 7.02 | 8.03 | 8.52 |
| CCC | 15.05 | 15.02 | 14.03 | 13.52 |

Source: CreditMetrics (Gupton et al., 1997, p.27)

Suppose that during the first year the borrower is upgraded from BBB to A. The bond will pay \$6 at the end of the next 4 years and \$106 at year 5.

$$V = 6 + \frac{6}{(1.0372)} + \frac{6}{(1.0432)^2} + \frac{6}{(1.0493)^3} + \frac{106}{(1.0532)^4} = 108.66$$

Based on the above the following will be the loan values (including the coupon):

Table 2-9 *Transition Matrix Example: Loan Values Including Coupon*

The table shows values at end of year 1 for a 5 year \$100 BBB loan. From the table we can see, for example, that if the loan rating was to improve to an AA rated loan at the end of the year, the value of the loan is \$109.19.

| Year-end rating | Value (\$) |
|---|---|
| AAA | 109.37 |
| AA | 109.19 |
| A | 108.66 |
| BBB | 107.55 |
| BB | 102.22 |
| B | 98.1 |
| CCC | 83.64 |
| Default | 51.13 |

Source: Credit Metrics (Gupton et al., 1997, p.28)

Table 2-10 shows VAR calculations for our BBB rated example.

Table 2-10 *Transition Matrix Example: VaR Calculation*

The table shows the calculation of the portfolio standard deviation from which VaR will be calculated. Probabilities are obtained from the Transition matrix in Table 2-7. The loan values in column B are the values at the one year horizon as per Table 2-9. Calculation methods are shown at the top of the columns.

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | Probability | New loan value plus coupon ($) | Probability weighted value (AxB) | Distance from mean | Distance from mean$^2$ ($D^2$) | Probability weighted difference$^2$ (AxE) |
| AAA | 0.02% | 109.37 | 0.02 | 2.28 | 5.21 | 0.0010 |
| AAA | 0.33% | 109.19 | 0.36 | 2.10 | 4.42 | 0.0146 |
| A | 5.95% | 108.66 | 6.47 | 1.57 | 2.47 | 0.1471 |
| BBB | 86.93% | 107.55 | 93.49 | 0.46 | 0.21 | 0.1856 |
| BB | 5.30% | 102.02 | 5.41 | -5.07 | 25.68 | 1.3612 |
| B | 1.17% | 98.10 | 1.15 | -8.99 | 80.78 | 0.9452 |
| CCC | 0.12% | 83.64 | 0.10 | -23.45 | 549.80 | 0.6598 |
| Default | 0.18% | 51.13 | 0.09 | -55.96 | 3131.29 | 5.6363 |
| Total | | | 107.09 | | | 8.9508 |
| **Mean (∑Column C)** | | | 107.09 | | | |
| **Variance (∑Column F)** | | | 8.95 | | | |
| **$\sigma$ = std deviation (sqrt variance)** | | | $2.99 | | | |

Source: CreditMetrics (Gupton et al., 1997, p.28)

Based on a normal distribution, a 95% confidence level over the 1 year horizon, gives VAR 1.65 x $\sigma$ = 4.93.

99% confidence level gives VAR 2.33 x $\sigma$ = $6.97.

Using the actual distribution, we have to go back to our table. Let us assume we wish to obtain 1% VaR. There is .18% probability of being in default, which is below 1%. There is 0.3% probability of being in CCC, which is also below 1%. The first level which exceeds 1% is B (1.17% or 98.83% confidence). The "approximate 1%" VAR at

B is the mean value less the actual value, i.e. \$107.09 – \$98.10 = \$8.99. The 6.7% VAR is a BB = \$107.09 – 102.02 = \$5.07.

The confidence levels are only approximations of 1% or 5%. These could be narrowed down using linear interpolation.

### *2.5.4.2.2. Transition Asset Thresholds and Monte Carlo Modelling*

Creditmetrics (Gupton et al., 1997, p.p.85-89) maintains that there is a series of asset values that determine a company's rating. If, for example, a company's asset value is \$100m and is BBB rated and this asset value falls below a certain level, at the end of that period, it's new asset value will determine the new rating at that point in time. These bands of asset values are referred to by Creditmetrics as asset thresholds. Making the assumption that returns are normally distributed, threshold values are calculated as follows:

Table 2-11 *One Year Transition Probabilities for a BB Rated Obligor*

Probabilities are obtained from the Transition Matrix (as described in Table 2-7. Asset thresholds (Z) are calculated as shown in the third column using the cumulative standard normal distribution (denoted by $\Phi$). Note that AAA does not have a threshold value as any value above the AA threshold will be AAA.

| **Rating** | **Probability from the transition matrix (%)** | **Threshold Value Calculation** | **Threshold Value** |
|---|---|---|---|
| AAA | 0.03% | $1 - \Phi(Z_{AA}/\sigma)$ | |
| AA | 0.14% | $\Phi(Z_{AA}/\sigma) - \Phi(Z_A/\sigma)$ | 3.43 $\sigma$ |
| A | 0.67% | $\Phi(Z_A/\sigma) - \Phi(Z_{BBB}/\sigma)$ | 2.93 $\sigma$ |
| BBB | 7.73% | $\Phi(Z_{BBB}/\sigma) - \Phi(Z_{BB}/\sigma)$ | 2.39 $\sigma$ |
| BB | 80.53% | $\Phi(Z_{BB}/\sigma) - \Phi(Z_B/\sigma)$ | 1.37 $\sigma$ |
| B | 8.84% | $\Phi(Z_B/\sigma) - \Phi(Z_{CCC}/\sigma)$ | -1.23 $\sigma$ |
| CCC | 1.00% | $\Phi(Z_{CCC}/\sigma) - \Phi(Z_{Def}/\sigma)$ | -2.04 $\sigma$ |
| Default | 1.06% | $\Phi(Z_{Def}/\sigma)$ | -2.30 $\sigma$ |

Source: CreditMetrics (Gupton et al., 1997, p.p.87-88)

CreditMetrics use the asset thresholds for Monte Carlo modelling (Gupton et al., 1997, p.p.113-119), which they propose as an alternate option to the Transition Matrix approach discussed so far. Whilst Monte Carlo modelling has not formed part of our scope so far, it becomes important when we examine Transition Matrix CVaR modelling (Section 2.7), as we use methodology developed from a key study on CVaR (Andersson, Mausser, Rosen, Uryasev 2000) which uses the CreditMetrics Monte Carlo approach. Thus we will describe this technique. Three steps are required by CreditMetrics.

The first step is to establish the asset return thresholds. Table 2-11 shows the thresholds for a BB rated asset (based on the S&P probability matrix), and similar tables are generated for each rating category.

The second step is to generate scenarios of asset returns using a normal distribution. We note that a computer programme such as Excel can throw out random numbers according to a normal distribution, i.e. with a mean of 0 and a standard deviation of 1.

The third step is to map the asset returns in Step 2 above with the credit scenarios in Step 1. A return falling below a rating corresponds to the rating above it.

Table 2-12 *Mapping Return Scenarios to Rating Scenarios*

The table shows ten scenarios that have been generated for 3 firms (using the S&P probabilities shown in Table 2-7. Asset returns are generated through random numbers, using the normal standard deviation. These are then mapped to new rating categories as shown in Table 2-11.

| | Asset Return | | | New Rating | | |
|---|---|---|---|---|---|---|
| **Scenario** | **Firm 1 (BBB)** | **Firm 2 (A)** | **Firm3 (CCC)** | **Firm 1 (BBB)** | **Firm 2 (A)** | **Firm3 (CCC)** |
| 1 | -0.7769 | -0.8750 | -0.6874 | BBB | A | CCC |
| 2 | -2.1060 | -2.0646 | 0.2996 | BB | BBB | CCC |
| 3 | -0.9276 | 0.0606 | 2.7068 | BBB | A | A |
| 4 | 0.6454 | -0.1532 | -1.1510 | BBB | A | Default |
| 5 | 0.4690 | -0.5639 | 0.2832 | BBB | A | CCC |
| 6 | -0.1252 | -0.5570 | -1.9479 | BBB | A | Default |
| 7 | 0.6994 | 1.5191 | -1.6503 | BBB | A | Default |
| 8 | 1.7780 | -0.6342 | -1.7759 | BBB | A | Default |
| 9 | 1.8480 | 2.1202 | 1.1631 | A | AA | B |
| 10 | 0.0249 | -0.4642 | 0.3533 | BBB | A | CCC |

Source: CreditMetrics (Gupton et al., 1997, p.116)

The above only shows 10 scenarios. In practice, thousands of scenarios are normally generated from which a portfolio distribution and VaR are calculated. In Section 2.7 we will examine how CVaR can be calculated using this approach.

### *2.5.4.3. CreditPortfolioView*

This section provides a summary of the model as presented by various sources, including Wilson (1998), Saunders & Allen (2002, p.p.107-120), Pesaran, Schuermann, Treutler & Weiner (2003, p.p.3-13), and Crouhy, Galai & Mark (2000, p.p.113-116).

CreditMetrics assumes that there is equal transition probability among borrowers of the same grade. Saunders & Allen ( 2002 p.107) show that this view has been challenged by various studies, for example Treacy and Carey (2000) and Wilson (1997).

KMV as we have already discussed, has a microeconomic approach which links asset value of a firm to probability of default.

CreditPortfolioView (CPV) links macroeconomic factors to migration probability. The model is also based on a Transition Matrix:

Table 2-13 *CreditPortfolioView Transition Matrix Approach*

The table shows the unconditional matrix, with each cell showing the probability of moving from 1 rating to another. The unconditional Transition Matrix is based on average of historical transitions. The conditional matrix is then obtained by multiplying each cell by a migration adjustment ratio incorporating economic factors, the calculation of which is discussed immediately after the table.

| Initial Rating | Rating at Year End A | B | C | D |
|---|---|---|---|---|
| A | $\rho_{AA}$ | $\rho_{AB}$ | $\rho_{AC}$ | $\rho_{AD}$ |
| B | $\rho_{BA}$ | $\rho_{BB}$ | $\rho_{BC}$ | $\rho_{BD}$ |
| C | $\rho_{CA}$ | $\rho_{CB}$ | $\rho_{CC}$ | $\rho_{CD}$ |
| D | $\rho_{DA}$ | $\rho_{DB}$ | $\rho_{DC}$ | $\rho_{DD}$ |

The model uses the current state of the economy to determine conditional transition probability, using factors such as GDP growth, unemployment rates and interest rates. The model groups firms into countries and industries. The probability of default is determined by an industry variable which is common to all firms in that industry. The model shows the probability that a firm in a given country and given industry, rated at a given grade at the start of the period, will move to another grade by the end of the period. The probability of firm moving from C to D, in a given country i and industry g over a given time period t (say 1 year) is given by the following:

$$\rho_{CDgit} = f(y_{git}) \qquad (2\text{-}15)$$

The probability is less than 0 with the probabilities for all the cells in a row adding to 1.

y is driven by a set of macroeconomic variables (X) as well as industry specific shocks V:

$$y_t = g(X_{it}, V_t) \tag{2-16}$$

The macroeconomic variables are influenced by their past histories and are also each subject to shocks themselves ($\varepsilon_{it}$):

$$X_{it} = h(X_{it-1}, X_{it-2,\ldots,}X_{it-p}, \varepsilon_{it}) \tag{2-17}$$

The conditional probability of transition can now be written as:

$$\rho_t = f(X_{it-p,}V_{t,}\ \varepsilon_{it,}) \tag{2-18}$$

A migration adjustment ratio $R_t$ is calculated as the unconditional probability divided by the conditional probability. Assume $\rho$ under current macroeconomic conditions ($\rho_{tc}$) is 0.19 and the number in the historic Transitional Matrix ($\rho_{th}$) is 0.16, then

$$R_t = \frac{\rho_{tc}}{\rho_{th}} \tag{2-19}$$

$$= \frac{.19}{.16} \qquad = 1.19.$$

We therefore need to adjust the transition factor for the next year by 1.19 (19%) & recalibrate each of the cells (remembering that the row must = 1). CPV provides standard values that can be chosen should the user not want to calculate all of the individual shifts. This can be used along with CreditMetrics to calculate an adjusted VAR figure.

#### *2.5.4.4. CreditRisk+*

The model is the product of Credit Suisse First Boston (1997). This section summarises their work as well as discussions on the model by Crouhy et al. (2000, p.p.107-113) and Saunders & Allen (2002, p.p.125-133).

The model applies an insurance approach to the calculation of VaR, and includes three steps. Firstly, calculate frequency of default. Secondly, calculate severity of default. Thirdly, from steps 1 and 2 produce distribution of default losses.

The model uses a number of assumptions. It is assumed that in a large portfolio of borrowers, the probability of default of each individual borrower is small. It is also assumed that the probability of default of any individual borrower is independent of the default of other borrowers, and that the probability of default in any period is independent of the probability of default of other periods.

Given the above, the probability of default of a portfolio is represented by a Poisson distribution:

$$P(\text{n defaults}) = \frac{\mu^n e^{-\mu}}{n!} \tag{2-20}$$

Where $\mu$ = mean number of faults in a given period (say 1 year)

! = factorial (product of the positive integers from 1 to $n$).

Assume the mean number of defaults in a portfolio is 3:

Probability of 1 default = = 0.149361 = 14.9%

Probability of 3 defaults = = 0.224042 = 22.4%

The probability of default distribution is shown in the following table:

Table 2-14 *CreditRisk+ Example: Probability of Default Distribution*

The probability of default of the portfolio is based on a Poisson distribution. In this example the 99th percentile shows just under 8 loans defaulting and the 95th percentile shows 6 loans defaulting.

| Number of Losses | Probability |
|---|---|
| 0 | 0.0497872 |
| 1 | 0.1493615 |
| 2 | 0.2240423 |
| 3 | 0.2240423 |
| 4 | 0.1680317 |
| 5 | 0.100819 |
| 6 | 0.0504095 |
| 7 | 0.0216041 |
| 8 | 0.0081015 |
| 9 | 0.0027005 |

Source: Based on similar examples in Crouhy et al. (2000, p.p.107-113) and Saunders & Allen (2002, p.p.130-131).

The model then estimates severity of losses. This is the amount of the loan at default less a recovery amount which gives the loss given default (LGD).

Distribution of default losses is obtained by grouping the LGD's into bands. For example, all loans LGD's <10,000 are rounded up to $10,000, all loans > 10,000 < $20,000 are rounded up to $20,000 and so on. Each of these bands is viewed as an independent portfolio.

So in our example, for the loans in the 10,000 band, the expected loss is 3 (mean) x 10,000 = 30,000. There is a 5% chance of no loss, 22.4% chance of 3 losses ($300,000) and a 0.8% chance of 8 losses ($800,000).

Assume that for the $20,000 band there is also an average of 3 loans defaulting, then we have a 22.4% chance of 3 losses ($60,000) and a 0.8% chance of 8 losses ($160,000).

So for this two band portfolio the distributions can be shown as follows:

Table 2-15 *CreditRisk+ Example: Two Band Portfolio Distributions*

The first two columns are calculated as per Table 2-14. The two bands ($10,000 and $20,000) bands are based on loss given default. The table shows, for example, that in the $10,000 band there is a 16% chance of 4 loans defaulting. The two bands are then aggregated in the final column which shows that the 99% level we have a portfolio VaR of just under 8 loans, or $240,000.

| Number of | | Band | | |
|---|---|---|---|---|
| Losses | Probability | $10,000 | $20,000 | Aggregate |
| 0 | 0.0497872 | $0 | $0 | $0 |
| 1 | 0.1493615 | $10,000 | $20,000 | $30,000 |
| 2 | 0.2240423 | $20,000 | $40,000 | $60,000 |
| 3 | 0.2240423 | $30,000 | $60,000 | $90,000 |
| 4 | 0.1680317 | $40,000 | $80,000 | $120,000 |
| 5 | 0.100819 | $50,000 | $100,000 | $150,000 |
| 6 | 0.0504095 | $60,000 | $120,000 | $180,000 |
| 7 | 0.0216041 | $70,000 | $140,000 | $210,000 |
| 8 | 0.0081015 | $80,000 | $160,000 | $240,000 |
| 9 | 0.0027005 | $90,000 | $180,000 | $270,000 |

Source: Based on similar examples in Crouhy et al. (2000, p.p.110-111) and Saunders & Allen (2002, p.p.131-134).

### *2.5.4.5. Reduced Form (Intensity) Models*

These models (as discussed in Allen, 2002; Choudhry, 2004, p.p.598-602; Jarrow, Lando, & Yu, 1999) make no assumptions about the causes of default (as compared to Structural models where default is the point where asset values fall below liability values). Instead they view default as an unexpected event (a jump to default). The model calculates the probability of default within a certain time period t (in a similar fashion to mortality models used in the insurance industry which calculate the probability of a person surviving until age t).

The Jarrow Lando and Turnbull model (1996, as cited in Choudhry, 2004, p.p.599-600), uses a Transition Matrix based on historical data. Each rating level of the Transition Matrix is given a probability of default (1 – recovery rate).

The historical Transition Matrix is adjusted by calibrating the values to the market values for risky bonds, with the adjusted matrix referred to as the risk neutral matrix.

The model assumes that all securities with the same rating have the same spread. Probability of default follows a Poisson process, and assumes default intensities are constant across firms in the same rating band and constant across business cycles.

Modified versions of this model have been produced by Das & Tufano (1996, as cited in Choudhry, 2004, p.600) who use stochastic recovery rates (i.e. spreads may change even though credit rating has not changed) and Duffie & Singleton (1998, as cited in Choudhry, 2004, p.601) who incorporate stochastic risk free rates and recovery rates.

## 2.6. Correlation

The discussions so far primarily relate to calculation of individual asset VaR. Each of the 3 models we have selected for further study also incorporate a portfolio approach which considers the extent to which the assets are related to each other, i.e. the correlation between the assets.

Work has been undertaken at the University of Western Australia on Spillover Effects in forecasting Volatility and VaR (McAleer & da Veiga, 2004). In a study of 3 multivariate GARCH models across four international portfolios, they found that the inclusion of spillover effects was not particularly important in forecasting VaR.

Our study will consider a different aspect to the work of McAleer & De Veiga. Their study looks at forecasting accuracy (as determined by backtesting). Our study will look at whether the inclusion of correlations has an impact on relative industry VaR.

This section will discuss correlation approaches used by each of the 3 models selected for further study, i.e. Equity (using Variance-covariance approach), Structural (using Merton-KMV approach) and Transition (using CreditMetrics approach).

### *2.6.1. Equity Correlation*

Single asset VaR has been discussed in Section 2.4.2. For 2 assets (x and y) we can use the following approach, based around discussions by Choudhry (2004, p.p.669-675).

Table 2-16 *Variance-Covariance Approach Example: 2 Asset Portfolio*

The table shows the calculation of VaR for a 2 asset portfolio (x and y). Steps 1 – 3 are calculated individually for each of the 2 assets. Steps 4-7 calculate the portfolio standard deviation through first calculating correlation coefficient, covariance and portfolio variance. The formulas for calculations are shown below the table. VaR is calculated based on the standard normal distribution as shown in steps 8 and 9.

| | X | Y |
|---|---|---|
| 1. Obtain relative weightings | 57.92% | 42.08% |
| 2. Obtain Stdev for each asset ($\sigma$)* | 12.40% | 16.13% |
| 3. Obtain variance for each asset ($\sigma^2$) | 0.01540 | 0.0260 |
| 4. Obtain correlation coefficient between the 2 assets* | 0.57012 | |
| 5. Obtain Covariance between the 2 assets* | 0.01141 | |
| 6. Use formula to calculate portfolio variance* | 0.01533 | |
| 7. Portfolio stdev = square root portfolio variance | 0.12380 | |
| 8. VaR 95% level normal distribution stdev (1.645) x portfolio stdev | 0.20366 | |
| 9. VaR 99% level normal distribution stdev (2.330) x portfolio stdev | 0.28845 | |

Source: Based on similar examples by Choudhry (2004, p.672)

If portfolio value = \$2.21m then VaR \$ at 95% confidence = \$ 0.45m. VaR at 99% confidence = 0.64m.

*Calculation is as follows:

*Standard deviation:*

This is annualized by multiplying the standard deviation of daily price relatives by the square root of the number of trading days per annum (usually 250 – which is also the number of days data required by Basel to measure market risk).

*Correlation coefficient:*

$$Correl_{(x,y)} = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}} = 0.57012 \qquad (2\text{-}21)$$

*Covariance:*

$$Co\,\mathrm{var}_{(x,y)} = Correl_{(x,y)} \times \sigma_x \times \sigma_y = 0.01141 \tag{2-22}$$

*Portfolio variance*

$$V_{port} = w^2{}_x\sigma^2{}_x + w^2{}_y\sigma^2{}_y + 2w_x w_y \sigma_x \sigma_y \rho_{xy} = 0.01533 \tag{2-23}$$

When dealing with multiple assets, a variance co-variance matrix needs to be used. Using the same two stocks in the above example:

$$\begin{bmatrix} \mathrm{var}\,iance\ x & \mathrm{cov}\,ariance\ xy \\ \mathrm{cov}\,ariance\ xy & \mathrm{var}\,iance\ y \end{bmatrix} \tag{2-24}$$

Or

$$\begin{bmatrix} \sigma\, x^2 & \sigma\, x.y \\ \sigma\, x.y & \sigma\, y^2 \end{bmatrix} \tag{2-25}$$

Example:

| | | | | | |
|---|---|---|---|---|---|
| Matrix formulae | | | | | |
| **Weightings** | | **VCV** | | **WVCV** | |
| $w_x$ | $w_y$ | $\sigma^2{}_x$ | $Cov_{xy}$ | $(\sigma^2{}_x w_x)+(cov_{xy} w_y)$ | $(\sigma^2{}_y w_y)+(cov_{xy} w_x)$ |
| | | $Cov_{xy}$ | $\sigma^2{}_y$ | | |
| **WVCV** | | **Weightings** | | **Portfolio Variance** | |
| $(\sigma^2{}_x w_x)+(cov_{xy} w_y)$ | $(\sigma^2{}_y w_y)+(cov_{xy} w_x)$ | $w_x$ | | $(wvcv_x w_x)+(wvcv_y w_y)$ | |
| | | $w_y$ | | | |
| | | Standard deviation | | $\sqrt{portfolio\ \mathrm{var}\,iance}$ | |
| Using our example: | | | | | |
| **Weightings** | | **VCV** | | **WVCV** | |
| 57.92% | 42.08% | 0.01538 | 0.01141 | 0.01371 | 0.01756 |
| | | 0.01141 | 0.02603 | | |
| **WVCV** | | **Weightings** | | **Portfolio Variance** | |
| 0.01371 | 0.01756 | 57.92% | | 0.01533 | |
| | | 42.08% | | | |
| | | Standard deviation | | 0.12380 | |

Source: Based on methodology described in Choudhry (2004, p.674), Mathworld (2005, p.1) and Riskglossary (2005a, p.1).

The above matrix method gives the same result as the formula previously used.

### *2.6.2. Structural Correlation*

KMV's Kealhofer & Bohn (1993, p.10-11) provide the following formula for calculating default correlation:

$$\frac{JDF - EDF_1 EDF_2}{\sqrt{EDF_1(1 - EDF_1)EDF_2(1 - EDF_2)}} \qquad (2\text{-}26)$$

$JDF$ = joint default frequency of firms 1 and 2 (probability of both defaulting together).

$$JDF = N_2(N^{-1}(EDF_1), N^{-1}(EDF_2), \rho_A \qquad (2\text{-}27)$$

$N_2$ ( ) = bivariate normal distribution function

$N$-1( ) = inverse normal distribution function

$\rho_A$ = correlation between the firm's asset returns

The correlation ($\rho_A$), can be obtained by calculating a time series analysis for each firm and then calculating a correlation between each pair of assets (i.e. in a similar manner to the method described for calculating correlations under the variance-covariance VaR approach described in section 2.6.1). KMV have instead adopted a factor modelling approach to their correlation calculation. KMV produce country and industry returns from their database of publicly traded firms, and their correlation model uses these indices to create a composite factor index for each firm depending on the industry and country. (D'Vari, Yalamanchili, & Bai, 2003, p.p. 5-6 ; Kealhofer & Bohn, 1993 p.p.12-15).

KMV (Zeng & Zhang, 2001), in an empirical comparison of asset correlation modelling approaches, found the KMV correlation model to outperform other modelling approaches examined in the study.

### 2.6.3. Transition Correlation

J.P. Morgan (Gupton et al., 1997, p.107-110) describe the following steps for the portfolio calculation (using a 3 asset portfolio example):

1. Calculate the mean values and standard deviations for each issue (as per Table 2-10).

2. To compute $\sigma_p$, we use the standard formula (noting this is the same basic formula as used in our variance-covariance VaR discussion):

$$\sigma_p^2 = \sigma^2(V_1) + \sigma^2(V_2) + \sigma^2(V_3) + 2.COV(V_1,V_2) + 2.COV(V_1,V_3) + 2.COV(V_2,V_3) \tag{2-28}$$

3. Noting that

$$\sigma^2(V_1 + V_2) = \sigma^2(V_1) + 2.COV(V_1,V_2) + \sigma^2(V_2) \tag{2-29}$$

4. We may express $\sigma_p$ by

$$\sigma_p^2 = \sigma^2(V_1 + V_2) + \sigma^2(V_1 + V_3) + \sigma^2(V_2 + V_3) - \sigma^2(V_1) - \sigma^2(V_2) - \sigma^2(V_3) \tag{2-30}$$

5. To complete calculation of $\sigma_p$, we need to identify each 2 asset sub-portfolio, calculate the standard deviations for each and then apply the above equation.

Once the joint probabilities have been completed, covariance and correlation can be determined using standard formulae:

$$COV(V_1,V_2) = \frac{\sigma^2(V_1 + V_2) - \sigma^2(V_1) - \sigma^2(V_2)}{2} \tag{2-31}$$

and

$$CORR(V_1,V_2) = \frac{COV(V_1,V_2)}{\sqrt{\sigma^2(V_1) \times \sigma^2(V_2)}} \tag{2-32}$$

## 2.7. Conditional Value at Risk

Conditional Value-at-Risk (CVaR) is closely related to VaR. CVaR is equal or greater than VaR. It is the conditional expected loss under the condition it exceeds VaR.

CVaR is also called mean excess loss, mean shortfall, or tail VaR. $\beta$-VaR is a value with probability $\beta$ the loss will not exceed $\beta$-VaR. CVaR is the mean value of the worst (1- $\beta$)*100% losses. For instance, if we are measuring VaR at a 95% confidence level ($\beta$=0.95), CVaR is the average of the 5% worst losses. (Uryasev & Rockafellar, 1999).

Section 2.4.5 discussed the limitations of VaR, in particular that it did not meet the requirements of 'coherent' risk measures such as subadditivity, monotonicity, positive homogeneity and translation invariance, and that it is was difficult to optimise VaR. Furthermore, VaR gives no indication of the losses that might be experienced at beyond the CVaR. By contrast CVaR does quantify the losses experienced in the tail end of the distribution. Pflug (2000) proved that VaR is a coherent risk measure, not reflecting the undesirable characteristics of VaR. A number of papers have also applied CVaR to portfolio optimisation problems, for example Rockafellar and Uryasev (1999 and 2002), Andersson et al. (2000), Alexander & Baptista (2003), and Alexander, Coleman & Li (2003). These optimisation techniques are beyond the scope of our study which deals with measurement of relative industry risk, rather than optimisation of a portfolio.

Whilst CVaR is primarily used in the insurance industry, it is also gaining in the credit industry. This is because credit losses are characterised by large number of small earnings and a small number of large losses. Thus the distribution is heavily skewed. VaR does not provide any information on the excess / extreme losses, but this is calculated by CVaR. Since CVaR is greater than or equal to VaR, portfolios with a high VaR also have a high CVaR.

In addition to providing a CVaR measurement, Uryasev and Rockafellar (1999) use optimization techniques to reduce the risks of high losses in the portfolio.

Creditmetrics Monte Carlo VaR methodology is discussed in section 2.5.4.2.2. As seen in Table 2-12, the process maps returns to ratings. Assuming a large number of scenarios were generated, the lowest 5% of returns can be mapped to ratings to create a portfolio of the lowest 5% of rated assets.

Application of the CVaR approach to credit risk portfolios, based on the Transition Matrix approach, is discussed in a study by Andersson, Mauser, Rosen and Uryasev (2000). The calculation of CVaR is obtained as the average of the losses beyond VaR using the Transition Matrix approach. Their sample included 197 bonds issued by 86 obligors in 29 countries. 20,000 scenarios were generated using Monte Carlo methodology, and correlated CVaR calculated based on the worst returns. Their study then calculated each country's percentage contribution to total CVaR. For example, their portfolio showed a total CVaR of $1,320m USD. Venezuela's contribution to this was $159m which is 12% of the portfolio. Venezuela was allocated a CVaR of 12% being their contribution to the portfolio. Venezuela's contribution was calculated as being the difference between the total portfolio risk, and the risk of the portfolio without Venezuela. Being a correlated CVaR, each country's contribution is less than their total exposure, and in Venezuela's case equated to 40% of their total CVaR exposure of $398m, equalling $159m. This 40% is termed marginal risk.

The idea behind calculating each country's CVaR as a percentage of the portfolio is to maximize returns by suppressing obligors with higher exposures.

CVaR can also be calculated using a normal distribution (parametric) approach, as follows (Huang, 2000):

$$CVaR_{\alpha} = \frac{\exp(-\frac{q_{\alpha}^{2}}{2})}{\alpha\sqrt{2\pi}}\sigma \qquad (2\text{-}33)$$

Where $q_{\alpha}$ is the tail $100_{\alpha}$ percentile of a standard normal distribution (e.g. 1.645 as obtained from standard distribution tables for 95% confidence).

Or using Excel at 95% confidence level, the formula is NORMINV(95%,mean,standard deviation).

## 2.8. Summary

The literature survey explored the Basel Accords, the Australian context, market and credit VaR methodologies, correlation techniques, and CVaR.

The Basel II framework seeks to align capital requirements with the individual risk profile of banks, placing a much greater focus on risk modelling. Requirements of the Accord are to be implemented from January 2008.

The Australian share market has experienced rapid growth over the last decade with the key share market indices being the S&P/ASX 200 and the All Ords index. Industries are categorised according to the global GICS system.

The Banking system in Australia is dominated by four major banks who hold a combined 72% market share. The bulk of business borrowers by number are small borrowers. However, larger borrowers (loans exceeding $2m) account for 75% of borrowings by value.

VaR calculates maximum expected losses over a given time period at a given tolerance level.

Market VaR has three main methods. The variance-covariance (parametric) method is the most widely used method by banks, and calculates VaR on the assumption of a normal distribution. The historical method is based on the actual historical worst losses. The Monte Carlo method simulates multiple scenarios.

A number of credit risk models have been explored. Historically, internal ratings systems, external ratings, and financial analysis models have been popular. Internal ratings systems incorporate elements such as historical repayment record, financial position of borrower and industry factors. External ratings are provided for larger entities by ratings services such as S&P, Moody's and Fitch. A table has been provided to map these ratings to each other. Financial statement models such as RiskCalc and z-score are based on key financial ratios.

Other Credit models explored include the Merton – KMV Structural approach, Transition Matrices, CreditPortfolioView, CreditRisk+, and Reduced Form (Intensity) models. The Structural method calculates probability of default (PD). This is based on the distance to default (DD), and an entity defaults when liabilities exceed the market value of assets. KMV use their world wide database to map DD to an Estimated Default Frequency (EDF). The Transition Matrix approach shows the probability of a borrower moving from one asset class to another. VaR is calculated from the standard deviation of probabilities, based on a standard normal distribution. CreditPortfolioView incorporates country and industry factors into a Transition Matrix, based on macroeconomic factors. CreditRisk+ apply an insurance approach, where PD is represented by a Poisson distribution. Reduced Form (Intensity) models make no assumptions about the causes of default, but view default as an unexpected event (a jump to default). They calculate PD within a certain time period (t) in a similar fashion to mortality models used in the insurance industry which calculate the probability of a person surviving until age t.

An important component of VaR modelling is not just to calculate the individual VaR of an asset, but to account for correlation between the assets in a portfolio. There is existing correlation methodology for all the models explored in this study, including parametric market methods, and Structural and Transition methodology.

CVaR is conditional on losses exceeding VaR, and has primarily been used in the insurance industry. It is gaining popularity as a measure of credit risk, with the recognition that high losses are often characterised by a small number of extreme events. CVaR also does not have some of the shortcomings of VaR such as subadditivity, monotonicity, positive homogeneity and translation invariance.

# 3. METHODOLOGY

## 3.1. Steps

Objectives for this study have been outlined in Section 1.2. Meeting these objectives entails the following steps:

1) Hypothesis formulation: This entails determining the questions that are to be answered by the research and then forming Hypotheses for each of these questions. This is done in Section 3.2.

2) Selecting and obtaining data for analysis. This is described in Section 3.3.

3) Calculating industry VaR separately for each model, including correlations and in the case of the Equity and Structural models, historical VaR. This is done via Excel. The analysis method for the Equity model is described in Section 3.4.1, the Structural model in Section 3.4.2 and the Transition model in Section 3.4.3.

4) Calculating industry CVaR separately for each model. This is also done via Excel. The analysis method for the Equity model is described in Section 3.5.1, the Structural model in Section 3.5.2, and the Transition model in Section 3.5.3.

5) Data analysis and Testing of Hypotheses. Methodology is described in Section 3. Presentation of results, analysis and hypothesis testing is undertaken in Section 4.

6) Development of Sector Indices and the new *i*Transition model (Section 5).

## 3.2. Formulation of Hypotheses

These hypotheses deal with the questions raised in Section 1.4. The hypotheses are stated in the alternate format.

### *3.2.1. Comparison of Industry VaR Between Models and Over Time*

We are interested in rankings rather than absolute values. It should be noted that comparison between models and over time will be restricted to the Equity and Structural models. This is because these two models use the same listed companies in their dataset and the same time frames, permitting valid comparisons between the models. Transition modelling is based on a different set of companies (those for which credit ratings are provided) and does not use time series data, thus analysis of this model is restricted to using different metrics within the model. These aspects are further considered under the data discussion in Section 3.3. It should be noted here that, for simplicity, reference to VaR in the hypotheses also includes PD, and reference to CVaR also includes CPD. Hypotheses relating to VaR comparison between models and over time include:

> **$H_1$:** There is association between the industry VaR rankings of the Structural and Equity models.

> **$H_2$:** Industry VaR does not stay constant over time.

### *3.2.2. Impact of VaR Diversification*

We test each of the 3 models for association between undiversified and diversified (correlated) approaches.

> **$H_3$:** There is association between undiversified VaR and diversified VaR within each model.

### *3.2.3. CVaR*

As with VaR, we are interested in rankings rather than absolute values. We test for CVaR / CPD ranking association within each model using different metrics. For the Structural and Equity models we also test for association between the models and for changes over time.

**$H_4$:** There is association between VaR industry rankings and CVaR industry rankings within each of the models.

**$H_5$:** There is association in CVaR industry rankings between the Structural and Equity models.

**$H_6$:** Industry CVaR does not stay constant over time.

**$H_7$:** There is association between parametric and nonparametric CVaR industry rankings within each of the models.

### 3.3. Data

Data is discussed in detail under each model below. In summary, the following is the data required and the source used.

1. Time series share price data (for Equity and Structural models) – obtained from Datastream.

2. Industry codes (for all entities analysed by each of the models) – for Equity and Structural models, this is obtained from the ASX website (as opposed to using the codes available on Datastream for reasons discussed in Section 3.3.1.2). For Transition Matrix entities these are obtained from Moody's and Standard & Poor's websites.

3. Market Capitalisation (for weighting of Equity model company data) – obtained from Datastream.

4. Total Liabilities and Debt for each company (for Structural and Transition models) – for listed entities obtained from Datastream. For Finance and Insurance Companies from APRA website. For other rated entities from data provided to the writer directly by Moody's (2005) and Standard and Poor's (2005a).

5. Risk free rate. For inclusion in Merton-KMV PD calculation. Rates obtained via internet from RBA interest rate data.

6. Credit ratings (for Transition model) – available on Moody's and Standard & Poor's websites.

7. Transition Matrix probabilities – Standard and Poor's matrices, as discussed in Section 2.5.4.2.1, are readily available, and their Global Transition Matrix (Standard & Poor's, 2005a, p.12) is used.

### 3.3.1. *Equity Model Data*

#### *3.3.1.1. Equity Data Requirements and Sources*

As discussed in the literature survey (Section 2.3.1), the All Ordinaries index ("All Ords") is considered to be Australia's share market indicator, consisting of the 500 largest listed shares, and representing more than 90% by value of the Australian stock exchange. The All Ords is therefore selected for this model. Data is obtained from Datastream. Daily share prices are obtained for the last 15 years which is the maximum available on Datastream. For market VaR, Basel requires 250 days data. This is only 1 year, and we are more concerned with a longer term perspective, spanning different economic conditions. For the advanced credit approach, Basel requires 7 years data (Bank for International Settlements, 2004, p.98). This study compares VaR between credit models and market models to ascertain whether there is a correlation between the industries that are risky from a credit perspective and those that are risky from a market perspective. For comparison purposes, and to meet our requirement for longer market perspectives, we use 7 year windows for calculating both market and credit VaR. This allows 9 years of comparative data (the first tranche being years 1-7, second tranche years 2-8, and so on until the $9^{th}$ tranche which represents the 7 years from 9 – 15 of our data sample). However, in order to consider the most recent trends, as well as consider longer term trends, we will also calculate VaR using 12 month time frames and compare it to our 7 year windows. Each year will consist of 250 daily observations (which is generally considered to represent the approximate number of working days).

#### *3.3.1.2. Equity Data Limitations & Considerations*

The data poses some limitations & considerations, such as the fact that the Datastream industry classifications are different from those used by the ASX, and that some industries have very few entities from which to make meaningful conclusions. The balance of this section outlines some of these issues and how we overcome them.

#### *3.3.1.2.1. Sector accuracy, classification and size*

The Datastream sectors are based on the UK FTSE sectors. As mentioned in section 2.3.1, ASX uses the international GICS system. Moody's & Standard & Poor's also use the GICS codes on their Australian websites. To ensure accuracy of classification, and to align with what is actually used on the ASX and by Moody's and Standard & Poor's, all industries in this study have been re-classified to GICS. This is done by obtaining individual GICS codes for each entity from the ASX website. For a few companies, GICS codes were not available, and this study has visited the website of each of these companies to obtain details of company operations, and assigned each company to the most appropriate sector.

Some sectors have only a very small number of companies in the All Ords. This raises the question as to how meaningful would conclusions be for these sectors? GICS codes consist of various sectors & sub-sectors. An option is to use the broad sector levels (per Table 2-2) as this would ensure greater numbers in each category than if sub-sector levels are used. However, such an approach would not differentiate between various sub-sectors. For example, using the sector 'Materials' does not differentiate between individual industries such as 'Mining' and 'Paper & Forest Products' This study, where possible, uses sub-sector levels to more accurately portray the risk associated with each industry. Therefore, wherever numbers permit meaningful analysis, we use sub-categories, and if necessary omit the sub-industries which have too small numbers for meaningful conclusions. For the time series analysis models (Equity and Structural) we have excluded only two sub categories on this basis, being 'Containers & Packaging' (1 company) and 'Diversified Consumer Services' (2 companies). We have also excluded all companies with historical data of less than 12 months. After all exclusions are made, there is a total of 458 companies used for analysis by our Equity and Structural models and each industry has a minimum of 5 companies. As the All Ords represent more than 90% of the value of listed Australian companies, we consider 5 entities to be sufficient to provide meaningful conclusions.

Taking into account the above changes (as well as the Structural exclusions discussed in Section 3.3.2), the revised Sector breakdown for the Equity and Structural models is shown below.

Table 3-1 *GICS Sectors*

The table shows the number of All Ords companies in each industry that are used in the Equity and Structural models in this study after excluding companies or industries with insufficient data, as discussed immediately above the table.

| **Industry** | **Number of Companies** | **Industry** | **Number of Companies** |
|---|---|---|---|
| Automobiles & Components | 5 | Insurance | 7 |
| Banks | 13 | Media | 18 |
| Capital Goods | 27 | Metals & Mining | 64 |
| Chemicals | 6 | Paper & Forest Products | 8 |
| Commercial Services & Supplies | 26 | Pharmaceuticals & Biotechnology | 23 |
| Construction Materials | 5 | Real Estate | 54 |
| Consumer Durables & Apparel | 7 | Retailing | 20 |
| Diversified Financials | 40 | Software & Services | 18 |
| Energy | 34 | Technology Hardware & Equipmer | 9 |
| Food & Staples Retailing | 6 | Telecommunication Services | 6 |
| Food Beverage & Tobacco | 15 | Transportation | 10 |
| Healthcare Equipment & Services | 17 | Utilities | 10 |
| Hotels Restaurants & Leisure | 10 | | |

Source: Compiled from a combination of Data obtained from Datastream and Standard and Poor's (2006b)

#### *3.3.1.2.2. Survivorship Bias*

This occurs when an index only includes current surviving companies and excludes failed entities (Brailsford & Heaney, 1998, p.229). This may cause a favourable bias in the results. An index such as the All Ords (and all other indices on the ASX) will not include failed companies as these would have been delisted.

We are not able to include all failed companies over the 15 years as the historical data for all of these is not available on Datastream. Standard and Poor's (2006a) provides information on all changes to the All Ords index over the past 5 years. deListed (2006) provides reasons for delistings, so we were able to ascertain which of these entities were delisted due to being placed in Administration or Receivership. From Datastream we were able to obtain historical data on those which had been delisted over the past 3 years. This amounts to 11 companies, spanning 7 industries. To test for the impact of survivorship bias we ran our Equity & Structural models with these companies included in our first rolling window and compared the VaR and PD results including failed companies to the results excluding failed companies. We tested for significance using the Spearman Rank Correlation Test (as described in Section 3.8.2.1). The results are shown in Table 3-2 and Table 3-3, with association found to be significant at the 99% level. We therefore consider survivorship bias not to have a significant impact on our study.

Table 3-2 *Survivorship Bias - VaR Significance Testing*

Undiversified VaR results excluding failed companies are compared with undiversified VaR results which include failed companies. Significance testing is undertaken using a Spearman Rank Correlation Test as described in Section 3.8.2.1.

| | Equity model | | | | | Structural model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Values | | Ranking | | | Values | | Ranking | | |
| **Industry** | **Failed Companies excluded** | **Failed Companies included** | **Failed Companies excluded** | **Failed Companies included** | **Difference in Ranks²** | **Failed Companies excluded** | **Failed Companies included** | **Failed Companies excluded** | **Failed Companies included** | **Difference in Ranks²** |
| Automobiles & Components | 0.5417 | 0.7357 | 7 | 3 | 16 | 0.0163 | 0.0323 | 5 | 2 | 9 |
| Banks | 0.3030 | 0.3030 | 25 | 25 | 0 | 0.0044 | 0.0032 | 9 | 16 | 49 |
| Capital Goods | 0.4591 | 0.4591 | 15 | 15 | 0 | 0.0039 | 0.0050 | 11 | 11 | 0 |
| Chemicals | 0.4215 | 0.4215 | 18 | 18 | 0 | 0.0031 | 0.0020 | 13 | 20 | 49 |
| Commercial Services & Supplies | 0.5380 | 0.5382 | 8 | 8 | 0 | 0.0057 | 0.0064 | 8 | 10 | 4 |
| Construction Materials | 0.4424 | 0.4424 | 17 | 17 | 0 | 0.0009 | 0.0017 | 22 | 21 | 1 |
| Consumer Durables & Apparel | 0.5294 | 0.5294 | 10 | 10 | 0 | 0.0024 | 0.0044 | 15 | 12 | 9 |
| Diversified Financials | 0.4145 | 0.4145 | 19 | 19 | 0 | 0.0005 | 0.0001 | 24 | 25 | 1 |
| Energy | 0.5904 | 0.5904 | 5 | 6 | 1 | 0.0021 | 0.0021 | 19 | 19 | 0 |
| Food & Staples Retailing | 0.3727 | 0.3729 | 23 | 23 | 0 | 0.0015 | 0.0016 | 21 | 22 | 1 |
| Food Beverage & Tobacco | 0.3987 | 0.3987 | 20 | 20 | 0 | 0.0022 | 0.0037 | 18 | 13 | 25 |
| Healthcare Equipment & Services | 0.5246 | 0.5246 | 11 | 11 | 0 | 0.0031 | 0.0036 | 14 | 14 | 0 |
| Hotels Restaurants & Leisure | 0.5147 | 0.5147 | 12 | 12 | 0 | 0.0024 | 0.0035 | 16 | 15 | 1 |
| Insurance | 0.5366 | 0.5366 | 9 | 9 | 0 | 0.0422 | 0.0292 | 1 | 3 | 4 |
| Media | 0.4561 | 0.4561 | 16 | 16 | 0 | 0.0016 | 0.0027 | 20 | 18 | 4 |
| Metals & Mining | 0.5595 | 0.5610 | 6 | 7 | 1 | 0.0038 | 0.0030 | 12 | 17 | 25 |
| Paper & Forest Products | 0.6713 | 0.6713 | 4 | 5 | 1 | 0.0172 | 0.0191 | 4 | 5 | 1 |
| Pharmaceuticals & Biotechnology | 0.6729 | 0.6733 | 3 | 4 | 1 | 0.0062 | 0.0090 | 7 | 7 | 0 |
| Real Estate | 0.3931 | 0.3931 | 21 | 21 | 0 | 0.0005 | 0.0010 | 23 | 23 | 0 |
| Retailing | 0.5077 | 0.5125 | 13 | 13 | 0 | 0.0083 | 0.0144 | 6 | 6 | 0 |
| Software & Services | 0.8412 | 0.8412 | 2 | 2 | 0 | 0.0176 | 0.0216 | 3 | 4 | 1 |
| Technology Hardware & Equipment | 0.9514 | 0.9514 | 1 | 1 | 0 | 0.0295 | 0.0392 | 2 | 1 | 1 |
| Telecommunication Services | 0.3640 | 0.3643 | 24 | 24 | 0 | 0.0022 | 0.0079 | 17 | 8 | 81 |
| Transportation | 0.4732 | 0.4732 | 14 | 14 | 0 | 0.0043 | 0.0072 | 10 | 9 | 1 |
| Utilities | 0.3777 | 0.3777 | 22 | 22 | 0 | 0.0001 | 0.0002 | 25 | 24 | 1 |
| | | | | | 20 | | | | | 268 |
| | | | | *n* | 25 | | | | *n* | 25 |
| | | | | *r* | 0.992 | | | | *r* | 0.897 |
| | | | | *t* | 38.442 | | | | *t* | 9.728 |
| | | | | *critical value 95%* | 2.069 | | | | *critical value 95%* | 2.069 |
| | | | | *critical value 99%* | 2.807 | | | | *critical value 99%* | 2.807 |
| | | | | *significance* | ** | | | | *significance* | ** |

*  denotes significance at the 95% confidence level

**  denotes significance at the 99% confidence level

We see from the above table that for the Equity model, Automobiles & Components has an increased risk as measured by VaR ranking when failed companies are included, shifting from 7th to 3rd ranking on the Equity model and from 5th to 2nd ranking on the Structural model. Any other ranking changes on the Equity model are only due to the changed ranking of Automobiles & Components.

The Structural Model shows more change in VaR rankings, with industries such as Automobiles & Components, Consumer Durables & Apparel, and Telecommunication Services showing increased risk ranking, and Banks, Chemicals and Insurance showing improved rankings.

Table 3-3 *Survivorship Bias – CVaR Significance Testing*

Nonparametric CVaR results excluding failed companies are compared to nonparametric CVaR results which include failed companies. Testing for significance is undertaken using a Spearman Rank Correlation Test as described in Section 3.8.2.1.

| | Equity model | | | | | Structural model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Values | | Ranking | | | Values | | Ranking | | |
| **Industry** | **Failed Companies excluded** | **Failed Companies included** | **Failed Companies excluded** | **Failed Companies included** | **Difference in Ranks$^2$** | **Failed Companies excluded** | **Failed Companies included** | **Failed Companies excluded** | **Failed Companies included** | **Difference in Ranks$^2$** |
| Automobiles & Components | 0.0536 | 0.0987 | 7 | 3 | 16 | 0.1104 | 0.1276 | 3 | 1 | 4 |
| Banks | 0.0268 | 0.0345 | 25 | 25 | 0 | 0.0750 | 0.0665 | 15 | 19 | 16 |
| Capital Goods | 0.0428 | 0.0508 | 15 | 16 | 1 | 0.0810 | 0.0836 | 9 | 12 | 9 |
| Chemicals | 0.0396 | 0.0456 | 17 | 20 | 9 | 0.0774 | 0.0709 | 12 | 17 | 25 |
| Commercial Services & Supplies | 0.0530 | 0.0608 | 8 | 9 | 1 | 0.0859 | 0.0881 | 8 | 10 | 4 |
| Construction Materials | 0.0390 | 0.0459 | 19 | 19 | 0 | 0.0586 | 0.0638 | 23 | 22 | 1 |
| Consumer Durables & Apparel | 0.0506 | 0.0646 | 10 | 6 | 16 | 0.0766 | 0.0904 | 13 | 9 | 16 |
| Diversified Financials | 0.0392 | 0.0485 | 18 | 18 | 0 | 0.0612 | 0.0375 | 22 | 25 | 9 |
| Energy | 0.0538 | 0.0629 | 6 | 8 | 4 | 0.0676 | 0.0668 | 19 | 18 | 1 |
| Food & Staples Retailing | 0.0343 | 0.0429 | 24 | 24 | 0 | 0.0644 | 0.0642 | 21 | 21 | 0 |
| Food Beverage & Tobacco | 0.0369 | 0.0502 | 21 | 17 | 16 | 0.0699 | 0.0828 | 17 | 13 | 16 |
| Healthcare Equipment & Services | 0.0499 | 0.0632 | 11 | 7 | 16 | 0.0798 | 0.0792 | 10 | 15 | 25 |
| Hotels Restaurants & Leisure | 0.0510 | 0.0567 | 9 | 11 | 4 | 0.0737 | 0.0804 | 16 | 14 | 4 |
| Insurance | 0.0586 | 0.0565 | 5 | 12 | 49 | 0.1206 | 0.1160 | 1 | 3 | 4 |
| Media | 0.0417 | 0.0515 | 16 | 15 | 1 | 0.0673 | 0.0760 | 20 | 16 | 16 |
| Metals & Mining | 0.0498 | 0.0582 | 12 | 10 | 4 | 0.0697 | 0.0623 | 18 | 23 | 25 |
| Paper & Forest Products | 0.0653 | 0.0768 | 4 | 4 | 0 | 0.1042 | 0.1054 | 5 | 5 | 0 |
| Pharmaceuticals & Biotechnology | 0.0656 | 0.0727 | 3 | 5 | 4 | 0.0903 | 0.0923 | 6 | 8 | 4 |
| Real Estate | 0.0381 | 0.0434 | 20 | 22 | 4 | 0.0576 | 0.0657 | 24 | 20 | 16 |
| Retailing | 0.0469 | 0.0543 | 13 | 14 | 1 | 0.0895 | 0.1000 | 7 | 7 | 0 |
| Software & Services | 0.0862 | 0.1026 | 2 | 2 | 0 | 0.1068 | 0.1157 | 4 | 4 | 0 |
| Technology Hardware & Equipment | 0.0964 | 0.1060 | 1 | 1 | 0 | 0.1167 | 0.1255 | 2 | 2 | 0 |
| Telecommunication Services | 0.0343 | 0.0447 | 23 | 21 | 4 | 0.0755 | 0.1027 | 14 | 6 | 64 |
| Transportation | 0.0451 | 0.0545 | 14 | 13 | 1 | 0.0794 | 0.0843 | 11 | 11 | 0 |
| Utilities | 0.0351 | 0.0432 | 22 | 23 | 1 | 0.0453 | 0.0540 | 25 | 24 | 1 |
| | | | | | 152 | | | | | 260 |
| | | | | ***n*** | 25 | | | | ***n*** | 25 |
| | | | | ***r*** | 0.942 | | | | ***r*** | 0.900 |
| | | | | ***t*** | 13.403 | | | | ***t*** | 9.902 |
| | | | | ***critical value 95%*** | 2.069 | | | | ***critical value 95%*** | 2.069 |
| | | | | ***critical value 99%*** | 2.807 | | | | ***critical value 99%*** | 2.807 |
| | | | | ***significance*** | ** | | | | ***significance*** | ** |

* denotes significance at the 95% confidence level

** denotes significance at the 99% confidence level

Again, the largest shift in the Equity model is experienced by Automobiles and Components with minor changes to some of the other rankings. For the Structural model, the changes in CVaR rankings closely mirror the changes in VaR rankings. As with VaR, there is significant association between CVaR rankings including failed companies and those excluding failed companies.

#### *3.3.1.2.3. Thin trading*

This problem occurs when infrequently traded companies are included in a time series analysis. Brailsford & Heaney (1998, p.p. 239-244) describe the effect as being most prominent in using daily share price data, but can also exist when using weekly or monthly data. Liquid (highly traded) assets are continually re-pricing based on market information. When thinly traded asset prices do change, they incorporate all the market information since the last trade.

This study uses daily price data as less frequent data does not capture the intervening volatility. A share could start and finish the week on the same price, but have experienced several up and down daily movements. In particular, it is important for the CVaR measure to incorporate all extreme price movements. This does give rise to potential thin trading problems, which can be reduced in the manners discussed below.

1. *Use larger highly traded assets.* This is the best way to avoid thinly traded assets. In our case we are using the All Ords index which consists of the top 500 companies on the ASX, thus avoiding the most thinly traded assets

2. *Apply an adjustment to thinly traded assets.* Some examples of thinly traded asset adjustments (not necessarily all suited to the VaR approach in our study) are:

   a) *Beta adjustments.* Dimson (1979) and Scholes and Williams (1977) provide beta adjustments for thin trading when testing the Capital Asset Pricing Model.

Dimson uses a single multiple regression, and Scholes and Williams use a combination of four regressions.

b) *Re-basing*. Volatility can be adjusted to reflect non-trading days as described by Sajit Das (1997) using an option example. This approach is to rebase an annualised volatility to a daily volatility (using $\sqrt{250}$ which is the normal number of annualisation days) and then recalculating it taking into account the number of non-trading days. This approach could also be applied to a VaR example, by re-basing thinly trading assets and adjusting for non-trading days.

c) *Regression.* Miller, Muthuswamy, and Whaley (1994, p.p. 479-513) suggest that a Moving Average model reflecting the number of non-trading days should be used to adjust returns. Due to difficulty in identifying non trading days, the approach shows that this is equivalent to estimating an AR (1) model from which the required adjustment can be determined. Their model involves the following regression equation :

$$R_t = a_1 + a_2 R_{t-1} + \varepsilon_t \tag{3-1}$$

The residual is then used to estimate the adjusted return as follows:

$$R_t^{adj} = \frac{\varepsilon_t}{(1-a_2)} \tag{3-2}$$

Where $R_t^{adj}$ = the return at time t with the thin trading adjustment.

The Miller, Muthuswamy, and Whaley adjustment is particularly suitable to time series equity studies (such as ours) and so we use this method to adjust for any thin trading.

### *3.3.2. Structural Model Data*

The equity component of this model requires the same data as the Equity model discussed in Section 3.3.1, and we use the same index (all ords), daily share price data and market capitalisation obtained from Datastream, and same GICS sector categories.

The model also requires long term debt, short term debt and total liabilities. This data is available from Datastream. Whilst historical debt and asset data is not available, this is not required for the model. The whole premise of the model is measuring the distance to the current default (debt) point based on the current value of the firm and the historical volatility of assets. The model measures historical asset volatility using a combination of current balance sheet data, and historical equity values which are then used to estimate historical asset values as described in Sections 2.5.4.1 and 3.4.2. Anchoring the default variable allows loss distribution to shift with changes in another variable, as is noted by Pesaran et al. (2003, p.10) whose credit risk model anchors default and determines loss distribution changes brought about by changes in macroeconomic factors. The authors note that "the problem is not properly identified if we allow both to be time varying".

A forecasting horizon of 1 year is selected as is common practice (refer Section 2.5.4.1).

A risk free rate is required by the model. The Reserve Bank of Australia (2006 - 2007) calculates Historical Indicative Mid Rates of selected Commonwealth Government Securities. We use the average 1 year mid rate for the 12 months to March 2006 (5.3%).

There are companies with insufficient balance sheet data to undertake the Structural analysis. These have been excluded from analysis. This number is not considered significant given that they are already included in the exclusions discussed in Section 3.3.1.2.1.

### 3.3.3. *Transition Model Data*

One of the objectives of this study is to identify, recognise, and where appropriate compensate for data and modelling limitations. The discussion below will show that the key limitation with using the Transition model in an Australian context is that data is not as readily available as for the Equity and Structural models. In general, we have obtained sufficient data to model ranking differences, but as discussed below, in some instances have had to make data compensations to present a complete modelling picture. However, it needs to be stressed that our key intention with this model is not to 100% accurately calculate VaR for each industry, but to use the model as a platform for developing a new modelling techniques, such as for CVaR (Section 3.5.3) and incorporation of market measurements into a Transition framework (Section 5.2). Thus for the Transition model, we are more interested in the theoretical concepts (using Australian data to illustrate these) than in complete accuracy of data. In practice, these data limitations would not affect banks using the model for credit purposes, as they would use their own internal data bases, default probabilities and yields to calculate VaR.

It is common practice to use the global S&P matrix for modelling & we use the following matrix:

Table 3-4 *Global Average One-Year Transition Rates, 1981 to 2004.*

The Transition Matrix shows the probability of a borrower moving from category to another. The final column is a 'not rated' category which (following the CreditMetrics approach discussed in 2.5.4.2.1) we exclude and adjust all remaining probabilities on a pro-rata basis. The adjusted table is included in Transition Worksheet 3 of Appendix 4.

| | AAA | AA | A | BBB | BB | B | CCC/C | D | NR |
|---|---|---|---|---|---|---|---|---|---|
| AAA | 87.44% | 7.37% | 0.46% | 0.09% | 0.06% | 0.00% | 0.00% | 0.00% | 4.59% |
| AA | 0.60% | 86.65% | 7.78% | 0.58% | 0.06% | 0.11% | 0.02% | 0.01% | 4.21% |
| A | 0.05% | 2.05% | 86.96% | 5.50% | 0.43% | 0.16% | 0.03% | 0.04% | 4.79% |
| BBB | 0.02% | 0.21% | 3.85% | 84.13% | 4.39% | 0.77% | 0.19% | 0.29% | 6.14% |
| BB | 0.04% | 0.08% | 0.33% | 5.27% | 75.73% | 7.36% | 0.94% | 1.20% | 9.06% |
| B | 0.00% | 0.07% | 0.20% | 0.28% | 5.21% | 72.95% | 4.23% | 5.71% | 11.36% |
| CCC/C | 0.08% | 0.00% | 0.31% | 0.39% | 1.31% | 9.74% | 46.83% | 28.83% | 12.52% |
| D | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |

Source: Standard & Poor's (2005b, p.12)

In a study on fixed interest in Australia, Carrett (2004, p.19) also uses a S&P matrix for modelling purposes and notes that it would be ideal to use a matrix based solely on Australian data but "the dearth of such data makes this an unworkable proposition. This combined with the belief that the rating agencies apply consistent principles across different jurisdictions, suggest that the use of such data is, on balance, a workable proposition". We are not suggesting that banks use the S&P matrix for their own purpose – they would use their own data.

A key data limitation with this model is that we cannot use the same All Ords dataset as we used for the Structural and Equity models– not all listed companies are rated. This makes data more difficult to obtain, and there are a lesser number of companies available for analysis. Ratings are also focussed more in certain industries than in others (e.g. banks, insurance companies, transport and utilities). Using a different dataset makes comparisons between models of questionable validity, and our analysis of the Transition model is therefore restricted to the model itself.

Only approximately 70 listed entities are rated by either Standard & Poor's or Moody's, providing too small a dataset to restrict the analysis to listed entities. However, the two rating agencies provide ratings for several unlisted companies. We use all the rated entities for which sufficient data is available, a total of 241 companies with a minimum of 5 entities per industry group (the same number of minimum entities as used for our Structural and Equity models). Given that external ratings are generally applied to companies of substantial size, this is considered to be sufficient companies to make meaningful conclusions. The Sector breakdown is shown in Table 3-5.

Table 3-5 *Transition Matrix Sector Breakdown*

The table shows the number of companies in each industry that are used in the Transition Matrix modelling in this study. They consist of all Moody's and S&P rated entities where sufficient data is available.

| **Industry** | **Number of Companies** |
|---|---|
| Banks | 37 |
| Diversified Financials | 42 |
| Energy | 7 |
| Food Beverage & Tobacco | 16 |
| Healthcare | 5 |
| Insurance | 33 |
| Media | 5 |
| Metals & Mining | 7 |
| Other Consumer Discretionary | 5 |
| Other Materials | 8 |
| Real Estate | 13 |
| Telecommunication Services | 6 |
| Transportation | 22 |
| Utilities | 35 |

Source: Compiled from a combination of data obtained from Datastream, Moody's Investor Services (2006) and Standard & Poor's (2006b)

Some of these companies are rated by Standard and Poor's and some by Moody's. We therefore map the Moody's ratings to the S&P ratings as per Table 2-5 in Section 2.5.2.

The companies included in the Transition Matrix needed to be weighted. Market capitalisation is not an appropriate method given that most of the companies are not listed, and that the model is a debt, not equity based model. We therefore weight according to debt. Where entities are listed, total debt figures on Datastream have been used. APRA provide debt figures for finance and insurance companies. Both Moody's and Standard and Poor's have provided the author with debt figures for all rated entities. Standard & Poor's provided their CreditStats (2005a) document for Australia & New Zealand, and Moody's with an Excel spreadsheet. Due to some differences in the debt calculation methodology between the two rating agencies, our analysis showed that an additional weighting figure of 0.275 to Moody's figures was appropriate to align with APRA and Standard & Poor's. Given that there was commonality in a number of entities (e.g. both Moody's and Standard & Poor's providing data for the same entities), we used the unweighted APRA and Standard & Poor's debt figures wherever possible.

The literature survey in Section 2.5.4.2.1 shows that CreditMetrics uses assumed forward zero curves to more accurately reflect the present value of debt instruments. D rated bonds would therefore have a much lower present value, including coupon, than for example an AAA bond. Yield information on Australian instruments is only readily available for investment grade bonds. However, as we are interested in rankings and modelling concepts rather than absolute values, the assumed framework provided by Creditmetrics is sufficient for our modelling purposes and we use this.

CreditMetrics adjust D probabilities by a recovery factor, based on historical recovery data. We do not have recovery factors for each rating category in Australia, and therefore cannot apply them. Again, however, we are interested in rankings rather than absolute values, and a D always ranks below a C whether the adjustment is applied or not. We are therefore able to exclude recovery factors without impacting on the ranking structure. This lack of public data will not affect banks as they will be able to apply recovery factors from their own database.

## 3.4. VaR Calculation

### *3.4.1. VaR Calculation – Equity Model*

VaR is calculated using the methodology described in Section 2.4.2 of the literature, with correlations as described in Sections 2.6.1. An Excel Spreadsheet was set up to capture the data and do the calculations. Specifically, the following steps were each undertaken on a separate spreadsheet (with a sample of each of the sheets shown in Appendix 2 for the Banking industry). Each industry is separately calculated. Following the numbering of each spreadsheet in Appendix 2, from Equity Worksheet 1 through to Equity Worksheet 12.

1. Data is downloaded from Datastream for each company, for each day for 15 years.

2. Each daily return is calculated, using the logarithm of price relatives.

3. Daily standard deviation is computed and annualised by multiplying by the square root of 250.

4. Weightings are calculated for each company according to market capitalisation.

5. Standard deviation for each company is weighted according to 4. above.

6. Correlation matrix is calculated, inclusive of all companies within the industry. This matrix is repeated for each rolling 7 year period.

7. Variance matrices are calculated inclusive of the companies and periods as per 6. above.

8. Variance-correlation matrices for each period are calculated via matrix multiplication of 6. and 7. above (using the Excel MMULT function).

9. Unweighted variance-covariance matrices are calculated via matrix multiplication of 7. and 8. above.

10. A weighted variance-covariance matrix is calculated through matrix multiplication of 4. and 9. above. Portfolio variance and standard deviation figures are obtained as described in Section 2.6.1.

11. Undiversified VaR is obtained, as described in Section 2.4.2., by multiplying the weighted undiversified standard deviation by 1.645 (as obtained from standard normal distribution tables for 95% confidence level).

12. Diversified VaR is obtained in the same manner as described in 11. above, but using the portfolio standard deviation obtained in 10. above (as described in Section 2.6.1).

### *3.4.2. PD Calculation – Structural Model*

PD is calculated using the methodology described in Section 2.5.4.1 of the literature, with correlations as described in Sections 2.6.2. Some of the data and calculations required are the same as for the Equity VaR model. Therefore we use the same Excel workbook as for the Equity VaR model, with additional worksheets where required. Specifically, the following steps are undertaken:

1. Market Value, Total Liabilities and Current Liabilities are obtained from Datastream and captured into the spreadsheet for each firm which forms part of the ASX All Ords index. Asset values are calculated using formula 2.3. Consistent with KMV, as described in section 2.5.4.1., debt is calculated as

the value of all current liabilities plus half the book value of all long term liabilities. This is shown in Structural Worksheet 1 of Appendix 3.

2. Equity returns and their standard deviation are calculated exactly the same as for steps 1-3 of the Equity model described in section 3.4.1 above.

3. Initial asset returns are estimated as described in Section 2.5.4.1, using formula 2.12. The asset returns derived above are applied to equation 2.8 to estimate the market value of assets every day. The daily log return is calculated and new asset values estimated. This process is repeated until asset returns converge, consistent with the approach described by Bharath and Shumway (2004, p.7), until difference in adjacent $\sigma$'s is less than $10^{-3}$.

4. We then follow the same steps and spreadsheets 2-10 as used for the Equity model (as per Section 3.4.1), except we are now using asset values derived in Step 3. above as opposed to the equity values used for the Equity model. Weightings are by asset values as opposed to the Market Capitalisation weightings used in the Equity model.

5. Annualised figures (standard deviation, weightings, weighted standard deviation, assets, asset returns, and debt) are extracted to separate spreadsheets as per Structural Worksheet 2 through to Structural Worksheet 7 of Appendix 3. These figures are used to calculate distance to default (per formula 2-13) and PD (formula 2-14 but adjusted as described in step 7 below). These are shown in Structural Worksheet 8 through to Structural Worksheet 10 of Appendix 3.

6. As discussed in the literature survey (section 2.6.2.), the Structural correlation can be determined through calculating a time series analysis for each firm and then calculating a correlation between each pair of assets (i.e. in a similar manner to the method described for calculating correlations under the Variance-covariance VaR approach). KMV have instead adopted a

factor modelling approach to their correlation calculation, based on country and industry factor indices obtained from their database of publicly traded firms. We do not have access to the KMV database or factors, and hence use the former (time series approach) with correlation calculations included in our step 4 above (and described in steps 6-10 of the Equity VaR model in section 3.4.1.) to derive a diversified standard deviation. The undiversified standard deviation that was used in the calculation of the undiversified DD and PD is substituted with the diversified standard deviation when calculating the diversified DD and PD. These are shown in Appendix 3 (Structural Worksheet 17).

7. As described in the literature survey (Section 2.5.4.1) KMV has a large worldwide database from which to provide empirically based EDFs. As also noted, EDFs are much larger than the PD's used by Merton (which yield very small values). We do not have access to the KMV database. However, this is not a problem for our study as we are interested in rankings rather than absolute values. DD, PD and EDF will all yield the same rankings because PD and EDF are all calculated from DD. Thus an instrument with a high DD will also have a high PD and EDF, and one with a low DD will also have a low PD and EDF. We could therefore base our rankings off the DD. However, although we do not have access to the KMV database, we are able to provide an estimated EDF. This is because we have calibrations between EDFs and S&P ratings (Table 2-5) and also between S&P and Moody's ratings (Table 2-6). Estimated EDF involves the following steps:

    i. Use the KMV / S&P / Moody's calibration tables to estimate EDF for each rated entity. For unrated entities we use the average of BBB+ through B-, this being the same rating band used by Basel II to risk weight unrated corporate entities (literature survey 2.2.5.1).

    ii. Obtain a weighted average and weighted standard deviation of the EDF's.

iii. Use the estimated EDF's to calculate an estimated DD. Formula 2.14 shows us that PD is calculated from DD by the formula $PD = N(-DD)$, so we use the inverse of this formula to calculate the DD from the EDF. Using Excel we use the formula *DD = –Normsinv(EDF)*

iv. Obtain the weighted average and weighted standard deviation of the actual DD's calculated in steps 1-6 above.

v. Match the standard deviation of the actual DD's to the standard deviation of the estimated DD's to obtain the EDF value. For example, assume a portfolio has an estimated weighted average DD of 2.65 and a standard deviation of 0.4. Assume the actual DD of an entity *a* is 0.5 standard deviations from the mean.

$$CDD = \overline{DD}_{eP} + \frac{DD_a - \overline{DD}_P}{\sigma_P} \sigma_{eP} \qquad (3\text{-}3)$$

Where

$\overline{DD}_{eP}$ = estimated weighted average DD for the portfolio based on KMV/S&P/Moody's matrix, as per step iii above

$\sigma_{eP}$ = standard deviation of above DD's

$\frac{DD_a - \overline{DD}_P}{\sigma_P}$ = number of standard deviations of actual DD of entity *a*.

In our example, CDD =2.65 + (0.5 x 0.4) = 2.85.

We can now calculate the CPD using formula 2.14, $= N(-2.85) = 0.22\%$. In this way, we obtain more meaningful values than the very small values normally provided by PD, without disturbing the ranking.

### *3.4.3. VaR Calculation – Transition Model*

VaR is calculated using the methodology described in Section 2.5.4.2 of the literature, with correlations as described in Sections 2.6.3. An Excel Spreadsheet has been set up to capture the data and do the calculations. Specifically, the following steps are each undertaken on a separate spreadsheet (with a sample of each of the Sheets shown in Appendix 4 for the Banking industry). Each industry is separately calculated. Following the numbering of each spreadsheet in Appendix 4:

1. Data has been obtained from Standard & Poor's and Moody's as described in Section 3.3.3. The data for each rated entity (for both S&P and Moody's) has been summarised into a spreadsheet, sorted alphabetically by rated entity, which includes columns for Company name, ASX code, Calibrated Rating (Moody's ratings calibrated to S&P rating as per Table 2-5 in the literature survey), Debt (as described in Section 3.3.3), and Industry.

2. Data is sorted into a table showing industry down the side and rating across the top. Ratings are grouped into the same categories as used by the S&P Transition Matrix (as per Table 3-4)

3. This sheet captures the S&P probability matrix and the forward values as described 2.5.4.2.1 of the literature survey.

4. – 7. Using the methodology shown in Table 2-10 in the literature survey, the following is calculated (separately for each industry): Probabilities of default for each loan rating; New loan value incorporating forward zero rates; Probability weighted value; Distance from mean squared; Distance from mean squared x probability; Variance ($); Standard Deviation ($).

8. – 12. Joint probabilities for each rating with each other rating are calculated as described in Section 2.6.3. and each of the items in step 4 above are calculated for each joint pair. The sample worksheet shows AAA / AA joint probabilities, and the same method is repeated for all the other ratings. Standard deviation and VaR are calculated as described in Section 2.5.4.2.1. Portfolio default probability, co-variance, correlations and portfolio VaR for each industry are calculated as described in Section 2.6.3.

### 3.5. CVaR Calculation

Section 2.7 shows that CVaR can be calculated using a parametric (normal distribution) approach, or can be based on the actual worst 5% of returns. We use a parametric approach to calculate VaR, therefore intuitively it makes sense to use this approach for CVaR. However this approach has some limitations. It will yield a ranking spread for CVaR that is the same as VaR, which may not be the case when considering actual CVaR returns and may not highlight the extreme returns. To highlight any differences, we use both parametric and nonparametric approaches.

The parametric approach is relatively simple to calculate. We just apply equation 2-33 to the standard deviation (noting that for the Structural model the revised standard deviation is then inserted into the DD formula).

For actual CVaR returns, there are more complexities and the balance of this section discusses these. Whilst the broad CVaR methodology discussed in section 2.7 of the literature survey is followed (i.e. using extreme returns), the VaR calculation methodology for each of our models is different, which necessitates a different CVaR calculation method for each model. An example of these differences is that Equity VaR is derived from the standard deviation of equity prices based on historical data, whereas the Structural model calculates standard deviation from historical asset (as opposed to equity) prices, and this is only one component of the distance to default and PD calculations. The Transition Matrix model is based on current data only, using credit ratings. In addition, the aims of the studies in the literature survey are different to our study. Whereas they focus on total portfolios, our primary focus is on the industries making up the portfolios.

Consistent with the studies in the literature survey, we identify the losses beyond VaR. As we have calculated VaR based on a 95% confidence level, CVaR is based on the worst 5% of losses. However, due to the differences discussed above, we then tailor CVaR methodology uniquely to each model, as discussed in Sections 3.5.1 – 3.5.3 below.

It should be noted that there is no nonparametric CVaR methodology identified in the literature survey for the Structural model. We therefore use our own method. As the Structural model uses PD rather than VaR, we will use the terminology CPD (conditional probability of default) for the Structural model as opposed to CVaR, with CPD also being based on the 5% of extreme returns.

### *3.5.1. CVaR Calculation – Equity Model*

1. Daily equity returns are based on the logarithm of price relatives as identified in steps 1 and 2 of section 3.4.1 above.

2. The extreme 5% of returns (those beyond VaR) are identified for each rolling 7 year period.

3. The extremes are averaged to obtain CVaR for each company.

4. Using weightings calculated in step 4 of section 3.4.1, the weighted average CVaR for each industry is calculated.

5. These calculations are incorporated in Equity Worksheet 13 through to Equity Worksheet 15 of Appendix 2.

### *3.5.2. CPD Calculation – Structural Model*

1. Daily asset returns are based on the logarithm of price relatives as calculated in step 3 of section 3.4.2.

2. The extreme 5% of returns are identified for each rolling 7 year period.

3. The average of the extreme 5% of returns is calculated.

4. Under normal distribution, if the average return changes, standard deviation changes proportionately. For example, a CVaR with average returns of 10% has double the distance from the mean than average portfolio returns of 5%. To calculate the conditional standard deviation (CStdev, the CVaR distance from the portfolio mean), we multiply the standard deviation for all returns by the percentage difference between all returns and the extreme 5% of returns (i.e. CStdev is double Stdev in our example).

5. 'Conditional DD' (CDD), i.e., the DD based on the extreme 5% returns, is calculated by substituting standard deviation with CStdev into formula 2.13 that was used to calculate DD.

6. CPD is calculated by substituting DD with CDD in formula into the PD formula 2.14., with CPD then being adjusted as per step 7 of Section 3.4.2 to obtain calibrated CPD.

7. These calculations are incorporated into Structural Worksheet 11 through to Structural Worksheet 18 of Appendix 3.

### *3.5.3. CVaR Calculation – Transition Model*

As mentioned in the literature survey (section 2.7), Andersson, Mauser, Rosen and Uryasev (2000) use the S&P Transition Matrix for calculating CVaR contribution to a portfolio (we will refer to this approach as the Portfolio Contribution approach). They calculate CVaR based on the worst 5% of returns using Monte Carlo simulation techniques. CVaR for each country in their study is calculated as a percentage of total CVaR, and the study looks to optimise portfolios by minimising CVaR. The main focus of our study is to ascertain the *relative* risk of each industry, which is not the same goal as Uryasev et. al (i.e. to optimise portfolios). To illustrate this difference, consider the following theoretical example. Assume we have two industries, Banks and Construction. Assume Banks have total assets of $10 billion and Construction only has total assets of $2 billion. Assume that after calculating returns (based on Transition Matrix probabilities) the worst 5% for each of the two industries is in category D (i.e. Banks have $0.5 billion in D and Construction has 0.1 billion in D). As we are interested in relative risk, we would consider the two industries to have equal CVaR as they have exactly the same extreme risk spread (5% in D). However, for the Portfolio Contribution approach, Banks will have a much higher CVaR as they contribute $0.5bn (83%) to CVaR and Construction only contribute $0.1 bn (17%) to CVaR, an entirely different result. We will use the Portfolio Contribution approach, but we also develop 2 alternate CVaR approaches to meet our study objectives. Both of these new approaches are based on measuring relative CVaR, but the one approach is a simple Analytical approach, whereas the other approach is based on more complex Monte Carlo methodology. We thus model 4 CVaR approaches in total, including the parametric method (already discussed in the opening paragraphs of Section 3.5) and the Analytical, Monte Carlo, and Portfolio Contribution approaches which are explained in Sections 3.5.3.1 to 3.5.3.3. below.

#### *3.5.3.1. Undiversified Analytical Approach*

We begin in the same manner as we do for calculating VaR, by using the same probability matrix and values to generate probability weighted asset returns. We then extract the worst 5% of these returns **for each industry** to a separate worksheet. We now follow a similar process to that we used for VaR (as described in Section 3.4.3, except that we are now using the lowest 5% of returns as opposed to all returns), to calculate probability weighted values, mean values, difference from mean (using forward values), and probability weighted difference from mean (which are then summed to form CVaR). These steps are all shown in Transition Worksheet 20 through to Transition Worksheet 25 in Appendix 4.

### *3.5.3.2. Monte Carlo Approach*

The first three steps below are as described in our literature survey in Section 2.5.4.2.2:

1. We generate an asset threshold table using the Standard & Poor's probability table as per Table 3-4.

2. We generate 20,000 scenarios of asset returns for each company (same number as Uryasev et. al.) using a normal distribution, via the Excel Data Analysis Random Number function.

3. We map these scenarios to the asset threshold table.

4. We select the lowest 5% of returns **for each industry**. We now follow the same process as for our Analytical model in Section 3.5.3.1 to calculate probability weighted values, mean values, difference from mean (using forward values), and probability weighted difference from mean (which are then summed to form CVaR). These steps are all illustrated in Transition Worksheet 13 through to Transition Worksheet 19 in Appendix 4.

We are therefore following most of the major steps of the Uryasev et al. Portfolio Contribution approach. The key difference, as explained, is that we are showing CVaR as a percentage of the debt values of each individual industry, rather than as a percentage of the aggregate portfolio.

#### *3.5.3.3. Portfolio Contribution Method*

We follow steps 1 – 3 as per our Monte Carlo approach. Then instead of selecting the worst 5% for each industry, we select the worst 5% of returns for the **overall portfolio**, and calculate each industry's contribution to the total portfolio. This is shown in Transition Worksheet 26 in Appendix 4.

## 3.6. Presentation of Data

This section provides a summary of the output tables provided by our models. Full tables are presented in the Results discussion in Section 4 (or cross referenced from Section 4 to the Appendices where appropriate). Table 3-6 provides an example of summary industry comparison data, and Table 3-7 provides an example of summary data for an individual industry.

Table 3-6 *Sample of Industry Comparison Output Data*

The table shows a sample of industry comparison output data for the Equity model. The sample shows 4 industries, but all industries are incorporated in the completed output tables in Section 4.1 to 4.3. Similar output is produced for each of the models. The Equity and Structural models also produce historical industry comparisons for VaR, Diversified VaR and CVaR in sections 4.4.2 and 4.4.6.

| **Industry** | **Number of Companies** | **Aggregate Market Capitalisation $m** | **Undiversified Standard Deviation** | **Annual Undiversified 95% VaR** | **Diversifed Standard Deviation** | **Diversified Portfolio 95% VaR** | **Daily Undiversified VaR** | **Daily Parametric CVaR** | **Daily Nonparametric CVaR** |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 5 | 940 | 0.3293 | 0.5417 | 0.1830 | 0.3010 | 0.0343 | 0.0430 | 0.0536 |
| Banks | 13 | 238684 | 0.1842 | 0.3030 | 0.1356 | 0.2231 | 0.0192 | 0.0240 | 0.0268 |
| Capital Goods | 27 | 29655 | 0.2791 | 0.4591 | 0.1440 | 0.2369 | 0.0290 | 0.0364 | 0.0428 |
| Chemicals | 6 | 10623 | 0.2562 | 0.4215 | 0.1888 | 0.3106 | 0.0267 | 0.0334 | 0.0396 |

Table 3-7 *Individual Industry Summary - Example*

An Equity model sample is provided below for Banks, showing a summary of key data for the industry, including historical data for the nine 7-year rolling windows. Full tables are contained in Appendix 5 and Appendix 6, with a table for each industry for Equity and Structural models.

| **Banks** | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 13 |
| Aggregate Market Capitalisation ($m) | | | | 238,683.6 |
| Undiversified Standard Deviation | | | | 0.18418 |
| Undiversified VaR | | | | 0.30297 |
| Diversified Standard Deviation | | | | 0.13560 |
| Diversified VaR | | | | 0.22305 |
| Daily CVaR | | | | 0.02402 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.22305 | 0.30297 | 0.01916 | 0.02402 |
| Year 2 | 0.23458 | 0.32065 | 0.02028 | 0.02542 |
| Year 3 | 0.25418 | 0.34213 | 0.02164 | 0.02713 |
| Year 4 | 0.27543 | 0.36219 | 0.02291 | 0.02872 |
| Year 5 | 0.27725 | 0.36464 | 0.02306 | 0.02891 |
| Year 6 | 0.26744 | 0.35545 | 0.02248 | 0.02818 |
| Year 7 | 0.26878 | 0.35246 | 0.02229 | 0.02795 |
| Year 8 | 0.26175 | 0.34522 | 0.02183 | 0.02737 |
| Year 9 | 0.25273 | 0.33844 | 0.02140 | 0.02683 |

### 3.7. Development of Sector Indices and Formulation of New Model

As outlined in the objectives in Section 1.2, this study (based on the results of our Equity and Structural modelling) will provide industry indices that can be used by banks, as well as develop a new model based on a Transition Matrix incorporating market derived industry factors. We do not discuss these aspects here under the Methodology section, as they are discussed in full in Section 5.

## 3.8. Hypothesis Testing and Data Analysis

### *3.8.1. Test Selection*

Parametric tests are generally used where there are large sets of data, where we are generally concerned with statistical measures such as standard deviation & means, and where we are assuming that observations are drawn from a normally distributed population.

Nonparametric tests are more suitable for smaller data sets where we are not making assumptions about distribution (for example where we are concerned about rankings rather than actual statistics such as means and standard deviations). This study uses nonparametric testing for the two reasons discussed below.

The first reason is the small size of the data sets. For comparison of industry VaRs across models we have 25 data items for each model, being the VaR / PD for each of the 25 industries. For comparison across time, we effectively have only 9 comparative periods for the Structural model, being the 9 seven year rolling windows (whilst we have daily standard deviations, this is only one component of the DD and PD calculations, which are calculated on an annual basis, yielding only the 9 annual DD and PD figures). For the Transition Matrix method there is no historical VaR, and hence this model is not included in the historical analysis.

Secondly, this study is more concerned with rankings rather than actual data. As discussed in the literature review, different models yield very different actual levels of risk and are calculated on a different basis (e.g. Equity VaR and Structural PD are not directly comparable on actual data but industries can be compared on a ranking basis).

Siegel & Castellan (1988) and Lee, Lee & Lee (2000, p.p.759-784) describe a range of parametric tests. The following two were considered suitable for our purposes:

The Spearman Rank Correlation Test compares 2 samples based on pure rankings and is therefore considered suitable for comparison between models. It is also suitable for testing comparison between diversified / undiversified and parametric / nonparametric rankings.

The Kruskal-Wallis Test tests variance of ranks where more than 2 populations are involved. This is considered suitable for comparisons between the 9 rolling window time periods.

These tests are described in section 3.8.2.

### *3.8.2. Test Description*

#### *3.8.2.1. Spearman Rank Correlation Test*

This is used to test

**$H_1$:** There is association between the industry VaR rankings of each model.

**$H_3$:** There is association between diversified VaR and undiversified VaR within each model.

**$H_4$:** There is association between VaR and CVaR rankings within each model.

**$H_5$:** There is association in CVaR industry rankings between the models.

**$H_7$:** There is association between Parametric and Nonparametric CVaR industry rankings within each model.

Using the methodology outlined by Lee et al. (2000 p.p.772-774) and Siegel & Castellan (1988, p.p.235-244), a rank correlation table is compiled, similar to Table 3-8 which uses theoretical data.

Table 3-8 *Spearman Rank Correlation Test*

This is a theoretical example of 10 industries, testing for association in industry risk ranking between 2 models (x and y). The risk rankings for model x and y are listed side by side, with the last two columns used to compute the sum of the differences in ranks$^2$. This is then used to calculate correlation as described under the table.

| **Industry** | **Risk Ranking, model x** | **Risk Ranking, model y** | **Difference in Ranks, d = x-y** | **Difference in Ranks, $d^2 = (x-y)^2$** |
|---|---|---|---|---|
| A | 5 | 3 | 2 | 4 |
| B | 3 | 4 | -1 | 1 |
| C | 6 | 6 | 0 | 0 |
| D | 1 | 1 | 0 | 0 |
| E | 2 | 10 | -8 | 64 |
| F | 10 | 8 | 2 | 4 |
| G | 4 | 2 | 2 | 4 |
| H | 9 | 5 | 4 | 16 |
| I | 8 | 9 | -1 | 1 |
| J | 7 | 7 | 0 | 0 |
| | | | | 94 |

Based on a similar example in Lee et al., (2000, p.773)

The correlation between two sets of ranked data is measured by the rank correlation coefficient $r_s$. For perfect correlation between two sets of data $r_s = 1$ and for perfect inverse correlation $r_s = -1$.

$$r_{s=}1-\frac{6\sum d^2}{n(n^2-1)} \qquad (3\text{-}4)$$

In our example,

$$r_{s=}1-\frac{6(94)}{10(10^2-1)} \qquad = 0.430$$

To test for significance using the Spearman Rank Correlation Test, some statisticians, for example Lee et al. (2000, p.773), use a $t$ test. Siegal and Castellan (1988, p.243) advise that the t test is slightly superior, but opt for a simpler $z$ test. We use the slightly superior $t$ test in this study. The significance of the statistic is measured by

$$t = \frac{r_S}{\sqrt{(1 - {r_S}^2)/(n-2)}} \tag{3-5}$$

$$t = \frac{0.43}{\sqrt{(1 - 0.43^2)/(10-2)}} \qquad = 1.348$$

Which has a $t$ distribution with (n-2) degrees of freedom.

Using a 2 tailed test, the critical $t$ at a 5% level of significance with 8 degrees of freedom is 2.306. We accept the null hypothesis of no rank correlation and conclude there is no linear relationship between rank in model $x$ and rank in model $y$.

### *3.8.2.2. Kruskal-Wallis Test*

The test is applied to

**$H_2$:** Industry VaR does not stay constant over time.

**$H_6$:** Industry CVaR does not stay constant over time.

Using the methodology outlined by Lee et al. (2000 p.p.769-771) and Siegel & Castellan (1988, p.p.206-215), a table is constructed, similar to the following table which uses theoretical data:

Table 3-9 *Kruskal-Wallis Test*

A theoretical example of 7 industries, comparing VaR risk rankings over 4 time periods. R is the sum of rankings for each time period and n is the number of industries in each time period. Calculations are described following the table.

| **Industry** | **Risk Ranking, Time Period 1** | **Risk Ranking, Time Period 2** | **Risk Ranking, Time Period 3** | **Risk Ranking, Time Period 4** |
|---|---|---|---|---|
| A | 25 | 6 | 27 | 21 |
| B | 20 | 1 | 5 | 11 |
| C | 14 | 15 | 12 | 22 |
| D | 24 | 3 | 17 | 23 |
| E | 10 | 4 | 7 | 19 |
| F | 18 | 13 | 2 | 16 |
| G | 8 | | 9 | 26 |
| *R* | 119 | 42 | 79 | 138 |
| *n* | 7 | 6 | 7 | 7 |
| $\sum n$ | 27 | | | |
| *degrees of freedom* | 3 | | | |
| *K* | 10.11 | | | |
| *Critical value* | 7.81473 | | | |

Based on a similar example in Lee et al., (2000, p.773)

The test statistic K compares variations in ranking means

$$K = \frac{12}{n(n+1)}\left(\sum_{i=1}^{c}\frac{R_i^2}{n_i}\right) - 3(n+1) \qquad (3\text{-}6)$$

Where

$n_i$ = number of observations in the *i*th sample

$n = n_1 + n_2 + n \ldots + n_c$ = total number of observations in the *c* samples

$R_i$= sum of the ranks for the *i*th sample

In our example, $K = \frac{12}{27(27+1)}\left(\frac{119^2}{7}+\frac{42^2}{6}+\frac{79^2}{7}+\frac{138^2}{7}\right) - 3(27+1) = 10.11$

The number of degrees of freedom is c-1 = 4 - 1 = 3.

Using a statistical table, the critical value of $x^2$ at 0.5% level of significance is 7.81473.

K > 7.81473, therefore we reject the null hypothesis of association in industry VaR over time and conclude there are significant differences over time.

## 3.9. Summary

Seven hypotheses have been formulated for various aspects of VaR and CVaR. This includes testing for association in industry rankings between models, over time, between diversified and undiversified VaR, and between parametric and nonparametric CVaR.

Hypotheses are tested using nonparametric testing, including the Spearman Rank Correlation Test and the Kruskal-Wallis Test.

Data for the Equity and Structural models is obtained from Datastream. We use 15 years of data, and GICS codes. Testing over time is undertaken in 7 year rolling windows, but we also compare data using 1 year time frames.

Data for the Transition model is obtained from a variety of sources, including Datastream, S&P, Moody's, and APRA. Lack of publicly available data is a key limitation of Transition modelling, and a reason for comparatively few studies being available on this topic. We are therefore able to provide insights into a topic that has not been thoroughly explored in the past. It is also noted that banks will not have this limitation, as they will use their own databases.

Equity, Structural, and Transition VaR and CVaR Models have been developed on Microsoft Excel. Model development has been a major part of the study.

The Equity model follows the variance-covariance parametric approach to VaR calculation, using diversified and undiversified approaches. Thin trading and survivorship bias have been considered, and adjustments made as appropriate. We incorporate CVaR methodology on a parametric (5% tail of the standard normal distribution) and nonparametric (5% actual worst returns) basis.

The Structural model is based on KMV-Merton methodology. We also develop new methodology, which computes Conditional Distance to Default (CDD) and Conditional Probability of Default (CPD) on both parametric and nonparametric bases.

The Transition model is based on the CreditMetrics VaR method. Existing CVaR methodology is modelled, as well as new methodology developed. CVaR approaches examined include Monte Carlo (20,000 simulations), Analytical (based on actual worst 5%), Parametric (tail end of normal distribution), and Portfolio Contribution (percentage contribution to CVaR portfolio).

The study develops industry VaR and CVaR indices which can be used by banks to better understand and manage industry risk. These indices can be incorporated into risk management aspects such as setting industry concentration limits or providing lending discretions to banks' officers on an industry basis. The study will also incorporate industry factors into Transition modelling without the need for the macroeconomic analysis that is not favoured by banks.

# 4. RESULTS

Sections 4.1- 4.3 present a summary of results of each of the 3 models. These are further discussed and compared in the hypothesis testing in Section 4.4. More detailed results are presented in Appendix 2 through to Appendix 6.

## 4.1. Equity Model

Results are summarised in Table 4-1. The table shows a noticeable reduction in VaR when using the diversified approach, with the portfolio VaR dropping from 45.16% to 26.75%. The impact of diversification is further discussed in Section 4.4.3.

The model rates the technology sectors as having the highest risk, with Technology Hardware & Equipment and Software & Services having the highest VaR scores. This is not surprising given the well known high volatility experienced in the technology sector over the past 7 years. Also ranked in the top undiversified risk quartile are Pharmaceuticals & Biotechnology, Paper & Forest Products, Energy, and Metals & Mining.

Lowest undiversified risk ranking is accorded to the Banking Sector. This is followed by Telecommunications, Food & Staples Retailing, Utilities, Real Estate, and Food, Beverage & Tobacco.

The results generally tend to show a lower VaR in essential / staple industries (e.g. Food & Beverage, Staples Retailing, Utilities, Banking) as opposed to discretionary and high technology ones (e.g. software, technology hardware, other retailing).

Table 4-1 *Equity Model - Results Summary*

The table shows VaR on both a diversified and undiversified basis. The undiversified approach being the weighted average of all the individual company VaRs and the diversified approach including the correlation of all the entities in the industry with each other. It should be noted that the table only includes the most recent 7 year rolling window. Historical data is discussed in Section 4.4.2. CVaR is obtained using both the parametric approach and the nonparametric approach. The parametric approach uses equation 2.33 to calculate undiversified CVaR and the nonparametric approach is calculated as the weighted average of the actual returns beyond VaR.

| **Industry** | **Number of Companies** | **Aggregate Market Capitalisation $m** | **Undiversified Standard Deviation** | **Annual Undiversified 95% VaR** | **Diversified Standard Deviation** | **Diversified Portfolio 95% VaR** | **Daily Undiversified VaR** | **Daily Parametric CVaR** | **Daily Nonparametric CVaR** |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 5 | 940 | 0.3293 | 0.5417 | 0.1830 | 0.3010 | 0.0343 | 0.0430 | 0.0536 |
| Banks | 13 | 238684 | 0.1842 | 0.3030 | 0.1356 | 0.2231 | 0.0192 | 0.0240 | 0.0268 |
| Capital Goods | 27 | 29655 | 0.2791 | 0.4591 | 0.1440 | 0.2369 | 0.0290 | 0.0364 | 0.0428 |
| Chemicals | 6 | 10623 | 0.2562 | 0.4215 | 0.1888 | 0.3106 | 0.0267 | 0.0334 | 0.0396 |
| Commercial Services & Supplies | 26 | 30875 | 0.3271 | 0.5380 | 0.1473 | 0.2424 | 0.0340 | 0.0427 | 0.0530 |
| Construction Materials | 5 | 26321 | 0.2689 | 0.4424 | 0.1943 | 0.3196 | 0.0280 | 0.0351 | 0.0390 |
| Consumer Durables & Apparel | 7 | 4301 | 0.3218 | 0.5294 | 0.2371 | 0.3901 | 0.0335 | 0.0420 | 0.0506 |
| Diversified Financials | 40 | 51828 | 0.2520 | 0.4145 | 0.1221 | 0.2008 | 0.0262 | 0.0329 | 0.0392 |
| Energy | 34 | 80045 | 0.3589 | 0.5904 | 0.1737 | 0.2858 | 0.0373 | 0.0468 | 0.0538 |
| Food & Staples Retailing | 6 | 44120 | 0.2266 | 0.3727 | 0.1495 | 0.2459 | 0.0236 | 0.0295 | 0.0343 |
| Food Beverage & Tobacco | 15 | 26734 | 0.2424 | 0.3987 | 0.1229 | 0.2022 | 0.0252 | 0.0316 | 0.0369 |
| Healthcare Equipment & Services | 17 | 16099 | 0.3189 | 0.5246 | 0.1382 | 0.2273 | 0.0332 | 0.0416 | 0.0499 |
| Hotels Restaurants & Leisure | 10 | 20165 | 0.3129 | 0.5147 | 0.1914 | 0.3148 | 0.0326 | 0.0408 | 0.0510 |
| Insurance | 7 | 58985 | 0.3262 | 0.5366 | 0.2052 | 0.3376 | 0.0339 | 0.0425 | 0.0586 |
| Media | 18 | 32306 | 0.2773 | 0.4561 | 0.1409 | 0.2317 | 0.0288 | 0.0362 | 0.0417 |
| Metals & Mining | 64 | 207728 | 0.3401 | 0.5595 | 0.2056 | 0.3382 | 0.0354 | 0.0444 | 0.0498 |
| Paper & Forest Products | 8 | 5373 | 0.4081 | 0.6713 | 0.2196 | 0.3612 | 0.0425 | 0.0532 | 0.0653 |
| Pharmaceuticals & Biotechnology | 23 | 16993 | 0.4091 | 0.6729 | 0.2262 | 0.3721 | 0.0426 | 0.0534 | 0.0656 |
| Real Estate | 54 | 115324 | 0.2390 | 0.3931 | 0.1124 | 0.1850 | 0.0249 | 0.0312 | 0.0381 |
| Retailing | 20 | 9535 | 0.3086 | 0.5077 | 0.1715 | 0.2821 | 0.0321 | 0.0403 | 0.0469 |
| Software & Services | 18 | 8845 | 0.5114 | 0.8412 | 0.2646 | 0.4353 | 0.0532 | 0.0667 | 0.0862 |
| Technology Hardware & Equipment | 9 | 1944 | 0.5784 | 0.9514 | 0.2953 | 0.4857 | 0.0602 | 0.0754 | 0.0964 |
| Telecommunication Services | 6 | 48911 | 0.2213 | 0.3640 | 0.2100 | 0.3455 | 0.0230 | 0.0289 | 0.0343 |
| Transportation | 10 | 38521 | 0.2877 | 0.4732 | 0.1482 | 0.2438 | 0.0299 | 0.0375 | 0.0451 |
| Utilities | 10 | 16933 | 0.2296 | 0.3777 | 0.1237 | 0.2035 | 0.0239 | 0.0299 | 0.0351 |
| | 458 | 1141788 | 0.2745 | 0.4516 | 0.1626 | 0.2675 | 0.0286 | 0.0358 | 0.0421 |

A study undertaken by Harper (2004b) in the U.S., using 10 year data, showed the S&P 500 to have an annualised standard deviation of 18.1% and the Nasdaq 28.8%. This equates to VaR of 29.8% and 47.4% respectively at the 95% confidence level. Our portfolio has a diversified VaR of 26.75%, which is fairly similar to the S&P 500, and the higher VaR experienced by our Technology shares is consistent with the higher VaR experienced by the Nasdaq which typically consists of high technology companies.

CVaR must always exceed VaR, as CVaR is based on the worst 5% of returns, and this is reflected in the results shown. Parametric CVaR has exactly the same ranking as VaR (CVaR is the tail end of the normal VaR distribution). Nonparametric CVaR is the average of actual returns beyond VaR, and tends to be slightly higher than parametric CVaR. Further discussion on CVaR is presented in Sections 4.4.4 to 4.4.7.

## 4.2. Structural Model

Table 4-2 provides a summary of results of our Structural modelling of PD and CPD.

Table 4-2 *Structural Model - Results Summary*

The table shows standard deviation and PD on both a diversified and undiversified basis. The undiversified approach being the weighted average of all the individual company PD's and the diversified approach including the correlation of all the entities in the industry with each other as per methodology in 2.6.2. PDs have been calibrated to EDF values as discussed in Section 3.4.2. It should be noted that the table only includes the most recent 7 year rolling window. Historical data is shown in Sections 4.4.2 and 4.4.6. The CPD shown is obtained using both the parametric approach and the nonparametric approach. The parametric approach uses equation 2.33 to calculate undiversified CPD and the nonparametric approach is calculated using the worst 5% of actual returns.

| **Industry** | **Number of Companies** | **Value of debt ($m)** | **$ Value of assets ($m)** | **Undiversified Stdev** | **Diversified Stdev** | **Undiversified PD** | **Diversified PD** | **Parametric CPD** | **Nonparametric CPD** |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 5 | 689 | 1801 | 0.1699 | 0.0944 | 0.0163 | 0.0012 | 0.0604 | 0.1104 |
| Banks | 13 | 1228391 | 1522163 | 0.0278 | 0.0204 | 0.0044 | 0.0007 | 0.0371 | 0.0750 |
| Capital Goods | 27 | 8462 | 39287 | 0.2062 | 0.1059 | 0.0039 | 0.0000 | 0.0354 | 0.0810 |
| Chemicals | 6 | 3111 | 14439 | 0.1851 | 0.1358 | 0.0031 | 0.0004 | 0.0327 | 0.0774 |
| Commercial Services & Supplies | 26 | 9152 | 42981 | 0.2317 | 0.1052 | 0.0057 | 0.0000 | 0.0408 | 0.0859 |
| Construction Materials | 5 | 4343 | 32174 | 0.2145 | 0.1554 | 0.0009 | 0.0000 | 0.0214 | 0.0586 |
| Consumer Durables & Apparel | 7 | 681 | 5154 | 0.2649 | 0.1944 | 0.0024 | 0.0003 | 0.0299 | 0.0766 |
| Diversified Financials | 40 | 85907 | 155700 | 0.0828 | 0.0397 | 0.0005 | 0.0000 | 0.0175 | 0.0612 |
| Energy | 34 | 14237 | 99276 | 0.2811 | 0.1361 | 0.0021 | 0.0000 | 0.0284 | 0.0676 |
| Food & Staples Retailing | 6 | 13521 | 59507 | 0.1641 | 0.1085 | 0.0015 | 0.0000 | 0.0252 | 0.0644 |
| Food Beverage & Tobacco | 15 | 11745 | 42991 | 0.1503 | 0.0760 | 0.0022 | 0.0000 | 0.0289 | 0.0699 |
| Healthcare Equipment & Services | 17 | 4347 | 22276 | 0.2234 | 0.0972 | 0.0031 | 0.0000 | 0.0327 | 0.0798 |
| Hotels Restaurants & Leisure | 10 | 3981 | 25297 | 0.2465 | 0.1500 | 0.0024 | 0.0000 | 0.0298 | 0.0737 |
| Insurance | 7 | 147597 | 205978 | 0.0938 | 0.0594 | 0.0422 | 0.0159 | 0.0883 | 0.1206 |
| Media | 18 | 9877 | 46928 | 0.1898 | 0.0965 | 0.0016 | 0.0000 | 0.0257 | 0.0673 |
| Metals & Mining | 64 | 44994 | 270330 | 0.2570 | 0.1554 | 0.0038 | 0.0001 | 0.0353 | 0.0697 |
| Paper & Forest Products | 8 | 3427 | 9633 | 0.2285 | 0.1235 | 0.0172 | 0.0011 | 0.0617 | 0.1042 |
| Pharmaceuticals & Biotechnology | 23 | 2640 | 20102 | 0.3456 | 0.1896 | 0.0062 | 0.0001 | 0.0422 | 0.0903 |
| Real Estate | 54 | 43060 | 176802 | 0.1520 | 0.0710 | 0.0005 | 0.0000 | 0.0180 | 0.0576 |
| Retailing | 20 | 3118 | 13366 | 0.2196 | 0.1212 | 0.0083 | 0.0002 | 0.0468 | 0.0895 |
| Software & Services | 18 | 1284 | 10422 | 0.4413 | 0.2281 | 0.0176 | 0.0008 | 0.0623 | 0.1068 |
| Technology Hardware & Equipme | 9 | 686 | 2679 | 0.4242 | 0.2151 | 0.0295 | 0.0029 | 0.0763 | 0.1167 |
| Telecommunication Services | 6 | 16202 | 72654 | 0.1565 | 0.1467 | 0.0022 | 0.0015 | 0.0291 | 0.0755 |
| Transportation | 10 | 19177 | 65323 | 0.1643 | 0.0846 | 0.0043 | 0.0000 | 0.0367 | 0.0794 |
| Utilities | 10 | 8863 | 31727 | 0.1201 | 0.0650 | 0.0001 | 0.0000 | 0.0101 | 0.0453 |
| | 458 | 1689494 | 2988991 | 0.1031 | 0.0610 | 0.0063 | 0.0015 | 0.0370 | 0.0756 |

Again, technology ranks high on the risk front with Technology Hardware & Equipment ranking number 2 for undiversified PD, and Software & Services ranked 3. Insurance ranks number 1. Also in the top risk quartile are Paper & Forest Products, Automobiles & Components and Retailing (other than Food & Staples).

Diversified PDs are much lower than undiversified ones. Whether this affects rankings to a significant extent is examined in Section 4.4.3.

Lowest risk is Utilities followed by Diversified Financials, Real Estate, Construction Materials, Food & Staples Retailing, and Media.

Whilst there are some similarities in the rankings when compared to the Equity model (such as the high risk ranking applicable to technology and the low risk ranking for Utilities and Food & Staples Retailing), there are also differences, such as the high risk ranking attributable to Banking. This is because of the impact of the balance sheet structure (e.g. the low equity ratios experienced in the Banking Sector). The significance of differences between the models is tested in Section 4.4.1.

Again, Parametric CPD rankings will be the same as PD rankings. Nonparametric CPD rankings are examined in Sections 4.4.4 to 4.4.7.

## 4.3. Transition Model

Results from the Transition Matrix modelling are summarised in Table 4-3.

Table 4-3. *Transition Model – Results Summary*

The table presents outputs from our VaR and CVaR modelling. VaR is based on CreditMetrics methodology as presented in Section 3.4.3. Parametric CVaR is the 5% tail end of the normal distribution, using formula 2.33.

| Industry | Number of Companies | Debt ($m) | Undiversified Standard Deviation | Undiversified 95% VaR | Diversified Standard Deviation | Diversified Portfolio 95% VaR | CVaR Parametric | CVaR Analytical | CVaR Monte Carlo |
|---|---|---|---|---|---|---|---|---|---|
| Banks | 37 | 401,070 | 0.0088 | 0.0145 | 0.0078 | 0.0128 | 0.0181 | 0.0131 | 0.0135 |
| Diversified Financials | 42 | 82,029 | 0.0175 | 0.0289 | 0.0082 | 0.0135 | 0.0362 | 0.0669 | 0.0658 |
| Energy | 7 | 5,935 | 0.0308 | 0.0506 | 0.0275 | 0.0453 | 0.0634 | 0.0579 | 0.0598 |
| Food Beverage & Tobacco | 16 | 21,685 | 0.0452 | 0.0743 | 0.0297 | 0.0488 | 0.0932 | 0.1787 | 0.1730 |
| Healthcare | 5 | 1,388 | 0.0565 | 0.0929 | 0.0560 | 0.0921 | 0.1164 | 0.1588 | 0.1629 |
| Insurance | 33 | 12,046 | 0.0126 | 0.0207 | 0.0091 | 0.0150 | 0.0259 | 0.0237 | 0.0232 |
| Media | 5 | 22,589 | 0.0324 | 0.0533 | 0.0259 | 0.0426 | 0.0668 | 0.0674 | 0.0722 |
| Metals & Mining | 7 | 30,827 | 0.0127 | 0.0209 | 0.0108 | 0.0177 | 0.0262 | 0.0212 | 0.0204 |
| Other Consumer Discretionary | 5 | 2,275 | 0.0449 | 0.0739 | 0.0303 | 0.0499 | 0.0926 | 0.1417 | 0.1412 |
| Other Materials | 8 | 10,068 | 0.0360 | 0.0592 | 0.0360 | 0.0592 | 0.0742 | 0.0685 | 0.0704 |
| Real Estate | 13 | 14,065 | 0.0200 | 0.0328 | 0.0136 | 0.0223 | 0.0412 | 0.0470 | 0.0454 |
| Telecommunication Services | 6 | 34,643 | 0.0125 | 0.0206 | 0.0094 | 0.0154 | 0.0258 | 0.0225 | 0.0222 |
| Transportation | 22 | 28,891 | 0.0311 | 0.0512 | 0.0255 | 0.0419 | 0.0642 | 0.0785 | 0.0805 |
| Utilities | 35 | 40,923 | 0.0215 | 0.0354 | 0.0167 | 0.0274 | 0.0444 | 0.0456 | 0.0459 |
| Total | 241 | 708,435 | 0.0147 | 0.0242 | 0.0076 | 0.0124 | 0.0304 | 0.0342 | 0.0343 |

From a VaR perspective, Healthcare is ranked by the model as being the highest risk followed by Other Consumer Discretionary and Food Beverage & Tobacco. The financial sector (Banks, Insurance, Diversified Financials) and Telecommunications have a low VaR.

From a nonparametric CVaR perspective, Food Beverage & Tobacco and Healthcare show the highest risk, with Banks and Insurance the lowest. CVaR methodology differences and similarities are further discussed in the Hypothesis Testing in Section 4.4.7.

We note here that the parametric VaR approach has some limitations. As it is based on a normal distribution, it can underestimate the VaR for portfolios that in reality have a fat tail, or overestimate VaR for those with a thin tail. Consider the example in Table 4-4.

Table 4-4. *Transition Model AA Portfolio*

The table provides an example of a theoretical portfolio, comprising only of AA rated entities, based on the methodology shown in Table 2-10.

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | Probability | New loan value plus coupon | Probability weighted value | Distance from mean | Distance from mean$^2$ | Probability weighted difference squared (AxE) |
| AAA | 0.63% | 109.37 | 0.68 | 0.26 | 0.0678363 | 0.0004 |
| AA | 90.44% | 109.19 | 98.75 | 0.08 | 0.00647285 | 0.0059 |
| A | 8.12% | 108.66 | 8.82 | -0.45 | 0.20209158 | 0.0164 |
| BBB | 0.61% | 107.55 | 0.65 | -1.56 | 2.43218365 | 0.0147 |
| BB | 0.06% | 102.02 | 0.06 | -7.09 | 50.2616622 | 0.0315 |
| B | 0.11% | 98.10 | 0.11 | -11.01 | 121.210103 | 0.1392 |
| CCC/C | 0.02% | 83.64 | 0.02 | -25.47 | 648.697772 | 0.1354 |
| Default | 0.01% | 51.13 | 0.01 | -57.98 | 3361.62775 | 0.3509 |

| | |
|---|---|
| Mean ( sum column C) | 109.11 |
| Variance(sum column F) | 0.6943 |
| standard deviation (sqrt variance) | 0.8333 |
| VaR 95% | 1.3707 |
| VaR 99% | 1.9415 |

In this instance VaR is \$1.37 at the 95% level, based on the normal distribution. However, we see from the above that based on the actual distribution, approximately 99% of the portfolio has a distance from the mean not exceeding \$0.45. In fact, when we calculate the actual CVaR of this portfolio, based on the worst 5% of returns it is only \$1.31, which is less than the VaR estimated by the normal distribution approach (i.e. VaR has been overestimated to the extent that it exceeds the actual CVaR). However, when we consider our results in Table 4-3, we see that this anomaly has only occurred with one industry (Banks), where the parametric VaR estimate is higher than actual CVaR. This has occurred due to Banks not following a normal distribution, with the vast bulk of the portfolio being in AA loans. However, as we are interested in rankings rather than actual values, this anomaly has no impact on our analysis, as VaR and CVaR approaches both rank Banks as having the lowest risk in the portfolio.

We also present results using the Portfolio Contribution method:

Table 4-5 *CVaR Using Portfolio Contribution Method*

The table shows CVaR calculated as each industry's contribution to the worst 5% of 20,000 Monte Carlo Simulations, as described in Section 3.5.3.3.

| **Industry** | **CVaR** |
|---|---|
| Banks | 0.0569 |
| Diversified Financials | 0.1738 |
| Energy | 0.0273 |
| Food Beverage & Tobacco | 0.1848 |
| Healthcare | 0.0328 |
| Insurance | 0.0057 |
| Media | 0.1308 |
| Metals & Mining | 0.0114 |
| Other Consumer Discretionary | 0.0210 |
| Other Materials | 0.0593 |
| Real Estate | 0.0280 |
| Telecommunication Services | 0.0149 |
| Transportation | 0.1402 |
| Utilities | 0.1133 |

The table shows that Food, Beverage & Tobacco and Diversified Financials have the highest contribution to the riskiest 5% of the portfolio.

The difference between our Monte Carlo method and the Portfolio Contribution. method is illustrated when comparing Diversified Financials and Other Consumer Discretionary. Consumer Discretionary has a much higher CVaR than Diversified Financials using our nonparametric CVaR approaches. But as Diversified Financials has a much higher portion of our total portfolio debt than Consumer Discretionary ($82bn as compared to $2bn), Diversified Financials has a much higher percentage than Other Consumer Discretionary using the Portfolio Contribution approach (the same principle accounting for the high percentage attributed to Food, Beverage and Tobacco).

## 4.4. Hypothesis Testing

Table 4-6 summarises the results of rank correlation testing using the Spearman Rank Correlation Test. Table 4-7 summarises Kruskal-Wallis hypothesis testing results. Each hypothesis is then individually discussed in Sections 4.4.1 through 4.4.7.

Table 4-6 *Hypothesis Testing Using the Spearman Rank Correlation Test*

The table shows tests of each hypothesis for significance at the 95% and 99% confidence levels. Hypotheses (alternate format) are shown in the first column. The nature of the test (diversified, undiversified, parametric, nonparametric) is indicated in the second column. If the test statistic (t) exceeds the critical value, then there is association in rankings.

| Hypothesis | Test | | | |
|---|---|---|---|---|
| $H_1$: There is association between the industry VaR rankings of each model | **Undiversified** | **Equity / Structural** | | |
| | *t* | 4.292 | | |
| | ***critical value 95%*** | 2.069 | | |
| | ***critical value 99%*** | 2.807 | | |
| | ***significance*** | ** | | |
| | **Diversified** | **Equity / Structural** | | |
| | *t* | 5.704 | | |
| | ***critical value 95%*** | 2.069 | | |
| | ***critical value 99%*** | 2.807 | | |
| | ***significance*** | ** | | |
| $H_3$: There is association between diversified VaR and undiversified VaR within each model | **Diversified / Undiversified** | **Equity** | **Structural** | **Transition** |
| | *t* | 4.153 | 5.264 | 9.413 |
| | ***critical value 95%*** | 2.069 | 2.069 | 2.179 |
| | ***critical value 99%*** | 2.807 | 2.807 | 3.055 |
| | ***significance*** | ** | ** | ** |
| $H_4$: There is association between VaR and CVaR rankings within each model | **Undiversified** | **Equity** | **Structural** | **Transition** |
| | *t* | 19.953 | 15.099 | 9.413 |
| | ***critical value 95%*** | 2.069 | 2.069 | 2.179 |
| | ***critical value 99%*** | 2.807 | 2.807 | 3.055 |
| | ***significance*** | ** | ** | ** |
| $H_5$: There is association in CVaR industry rankings between the models | **Parametric** | **Equity / Structural** | | |
| | *t* | 4.292 | | |
| | ***critical value 95%*** | 2.069 | | |
| | ***critical value 99%*** | 2.807 | | |
| | ***significance*** | ** | | |
| | **Nonparametric** | **Equity / Structural** | | |
| | *t* | 5.157 | | |
| | ***critical value 95%*** | 2.069 | | |
| | ***critical value 99%*** | 2.807 | | |
| | ***significance*** | ** | | |
| $H_7$: There is association between Parametric and Nonparametric CVaR industry ranking within each model | **Parametric / Nonparametric** | **Equity** | **Structural** | **Transition** |
| | *t* | 19.953 | 15.099 | 9.413 |
| | ***critical value 95%*** | 2.069 | 2.069 | 2.179 |
| | ***critical value 99%*** | 2.807 | 2.807 | 3.055 |
| | ***significance*** | ** | ** | ** |

* denotes significance at the 95% confidence level

** denotes significance at the 99% confidence level

Table 4-6 tells us that there is association between the Structural and Equity models for diversified and undiversified VaR, as well as parametric and nonparametric CVaR. Within each of the 3 models there is rank association between diversified and undiversified VaR, VaR and CVaR, and parametric and nonparametric CVaR.

Table 4-7 *Hypothesis Testing Using the Kruskal-Wallis Test*

The table shows tests of each hypothesis (shown in alternate format) for significance in differences over time at the 95% and 99% confidence levels. Hypotheses are shown in the first column. The nature of the test (diversified, undiversified, parametric, nonparametric) is indicated in the second column. If the test statistic (K) is less than the critical value, then we accept the null hypothesis of no difference over time.

| Hypothesis | | Equity | Structural |
|---|---|---|---|
| **$H_2$**: Industry VaR rankings do not stay constant over time | **Diversified (rolling 7 yr)** | **Equity** | **Structural** |
| | ***K*** | 11.808 | 5.259 |
| | ***critical value 95%*** | 15.507 | 15.507 |
| | ***critical value 99%*** | 20.090 | 20.090 |
| | ***significance*** | - | - |
| | **Undiversified (rolling 7 yr)** | **Equity** | **Structural** |
| | ***K*** | 5.542 | 10.085 |
| | ***critical value 95%*** | 15.507 | 15.507 |
| | ***critical value 99%*** | 20.090 | 20.090 |
| | ***significance*** | - | - |
| | **Undiversified (1yr)** | **Equity 1yr** | **Structural 1yr** |
| | ***K*** | 51.980 | 52.440 |
| | ***critical value 95%*** | 15.507 | 15.507 |
| | ***critical value 99%*** | 20.090 | 20.090 |
| | ***significance*** | ** | ** |
| **$H_6$**: Industry CVaR rankings do not stay constant over time | **Parametric** | **Equity** | **Structural** |
| | ***K*** | 5.542 | 10.085 |
| | ***critical value 95%*** | 15.507 | 15.507 |
| | ***critical value 99%*** | 20.090 | 20.090 |
| | ***significance*** | - | - |
| | **Nonparametric** | **Equity** | **Structural** |
| | ***K*** | 3.599 | 4.527 |
| | ***critical value 95%*** | 15.507 | 15.507 |
| | ***critical value 99%*** | 20.090 | 20.090 |
| | ***significance*** | - | - |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

Table 4-7 tells us that there are no significant differences in Industry VaR over time for both the Equity and Structural models, for parametric and nonparametric approaches, using our 7 year window method. But there are significant differences over time using 1 year windows. It also shows that industry CVaR does not differ significantly over time for both the Equity and Structural models, for parametric and nonparametric approaches (7 year windows).

### 4.4.1. $H_1$: *There is association between the industry VaR rankings of the Structural and Equity models.*

Table 4-8 *VaR Comparison Between Equity and Structural Models*

The table makes a comparison between the models for undiversified VaR on the left side of the table and for diversified (correlated) VaR on the right side of the table. The test applied is a Spearman Rank Correlation Test.

| | **Annual Undiversified 95% VaR:** | | | | | **Annual Diversified 95% VaR:** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Values** | | **Ranking** | | **Difference in Ranks²** | **Values** | | **Ranking** | | **Difference in Ranks²** |
| **Industry** | **Equity Model VaR** | **Structural Model PD** | **Equity Model VaR** | **Structural Model PD** | **Equity / Structural** | **Equity Model VaR** | **Structural Model PD** | **Equity Model VaR** | **Structural Model PD** | **Equity / Structural** |
| Automobiles & Components | 0.5417 | 0.0163 | 7 | 5 | 4 | 0.3010 | 0.0012 | 12 | 4 | 64 |
| Banks | 0.3030 | 0.0044 | 25 | 9 | 256 | 0.2231 | 0.0007 | 21 | 7 | 196 |
| Capital Goods | 0.4591 | 0.0039 | 15 | 11 | 16 | 0.2369 | 0.0000 | 18 | 17 | 1 |
| Chemicals | 0.4215 | 0.0031 | 18 | 13 | 25 | 0.3106 | 0.0004 | 11 | 8 | 9 |
| Commercial Services & Supplies | 0.5380 | 0.0057 | 8 | 8 | 0 | 0.2424 | 0.0000 | 17 | 18 | 1 |
| Construction Materials | 0.4424 | 0.0009 | 17 | 22 | 25 | 0.3196 | 0.0000 | 9 | 13 | 16 |
| Consumer Durables & Apparel | 0.5294 | 0.0024 | 10 | 15 | 25 | 0.3901 | 0.0003 | 3 | 9 | 36 |
| Diversified Financials | 0.4145 | 0.0005 | 19 | 24 | 25 | 0.2008 | 0.0000 | 24 | 23 | 1 |
| Energy | 0.5904 | 0.0021 | 5 | 19 | 196 | 0.2858 | 0.0000 | 13 | 21 | 64 |
| Food & Staples Retailing | 0.3727 | 0.0015 | 23 | 21 | 4 | 0.2459 | 0.0000 | 15 | 14 | 1 |
| Food Beverage & Tobacco | 0.3987 | 0.0022 | 20 | 18 | 4 | 0.2022 | 0.0000 | 23 | 19 | 16 |
| Healthcare Equipment & Services | 0.5246 | 0.0031 | 11 | 14 | 9 | 0.2273 | 0.0000 | 20 | 22 | 4 |
| Hotels Restaurants & Leisure | 0.5147 | 0.0024 | 12 | 16 | 16 | 0.3148 | 0.0000 | 10 | 15 | 25 |
| Insurance | 0.5366 | 0.0422 | 9 | 1 | 64 | 0.3376 | 0.0159 | 8 | 1 | 49 |
| Media | 0.4561 | 0.0016 | 16 | 20 | 16 | 0.2317 | 0.0000 | 19 | 20 | 1 |
| Metals & Mining | 0.5595 | 0.0038 | 6 | 12 | 36 | 0.3382 | 0.0001 | 7 | 12 | 25 |
| Paper & Forest Products | 0.6713 | 0.0172 | 4 | 4 | 0 | 0.3612 | 0.0011 | 5 | 5 | 0 |
| Pharmaceuticals & Biotechnology | 0.6729 | 0.0062 | 3 | 7 | 16 | 0.3721 | 0.0001 | 4 | 11 | 49 |
| Real Estate | 0.3931 | 0.0005 | 21 | 23 | 4 | 0.1850 | 0.0000 | 25 | 24 | 1 |
| Retailing | 0.5077 | 0.0083 | 13 | 6 | 49 | 0.2821 | 0.0002 | 14 | 10 | 16 |
| Software & Services | 0.8412 | 0.0176 | 2 | 3 | 1 | 0.4353 | 0.0008 | 2 | 6 | 16 |
| Technology Hardware & Equipment | 0.9514 | 0.0295 | 1 | 2 | 1 | 0.4857 | 0.0029 | 1 | 2 | 1 |
| Telecommunication Services | 0.3640 | 0.0022 | 24 | 17 | 49 | 0.3455 | 0.0015 | 6 | 3 | 9 |
| Transportation | 0.4732 | 0.0043 | 14 | 10 | 16 | 0.2438 | 0.0000 | 16 | 16 | 0 |
| Utilities | 0.3777 | 0.0001 | 22 | 25 | 9 | 0.2035 | 0.0000 | 22 | 25 | 9 |
| | | | | | 866 | | | | | 610 |
| | | | | ***n*** | 25 | | | | ***n*** | 25 |
| | | | | ***r*** | 0.667 | | | | ***r*** | 0.765 |
| | | | | ***t*** | 4.292 | | | | ***t*** | 5.704 |
| | | | | ***critical value 95%*** | 2.069 | | | | ***critical value 95%*** | 2.069 |
| | | | | ***critical value 99%*** | 2.807 | | | | ***critical value 99%*** | 2.807 |
| | | | | ***significance*** | ** | | | | ***significance*** | ** |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

As seen in Table 4-8, on an undiversified basis both models rank Technology Hardware & Equipment and Software and Services as being at the top end of the risk scale. Pharmaceuticals & Biotechnology, Paper & Forest Products and Automobiles and components are also found by both models to have a high VaR. Industries found by both models to have a relatively low risk ranking include Diversified Financials, Real Estate, Utilities, Food Beverage & Tobacco, and Food and Staples Retailing. Relatively larger differences exist in rankings for Banks, Energy, Insurance, Retailing, and Telecommunications due to balance sheet structural differences.

These differences are not significant, as there is significant association in rankings at the 99% level, and thus we reject the null hypothesis of no association between the industry VaR rankings of the Structural and Equity models. Similarly, there is association between the two models for diversified VaR. Diversification is discussed in further detail in Section 4.4.3.

If we condense the industries into their higher level sectors, per Table 4-9 we see Information Technology showing the highest risk, and Consumer Staples, Utilities and Telecommunications being relatively lower risk. Financials (which includes the large difference in Insurance) and Energy show the largest differences between the models.

Table 4-9 *High Level Sector Undiversified VaR Comparison of Equity and Structural Models*

The table shows higher level sectors of GICS codes. For a summary of these sectors, refer Table 2-2.

| | **Equity model** | | **Structural Model** | |
|---|---|---|---|---|
| | **VaR** | **Ranking** | **PD** | **Ranking** |
| Information Technology | 0.8611 | 1 | 0.0200 | 1 |
| Healthcare | 0.6008 | 2 | 0.0046 | 3 |
| Energy | 0.5904 | 3 | 0.0021 | 8 |
| Materials | 0.5437 | 4 | 0.0039 | 5 |
| Industrials | 0.4892 | 5 | 0.0046 | 4 |
| Consumer Discretionary | 0.4869 | 6 | 0.0031 | 6 |
| Consumer staples | 0.3825 | 7 | 0.0018 | 9 |
| Utilities | 0.3777 | 8 | 0.0001 | 10 |
| Financials | 0.3674 | 9 | 0.0076 | 2 |
| Telecommunication Services | 0.3640 | 10 | 0.0022 | 7 |
| Total | 0.4516 | | 0.0063 | |

### 4.4.2. $H_2$: *Industry VaR does not stay constant over time.*

Table 4-10 shows Equity model VaR for each industry over time.

Table 4-10 *Equity Model – Undiversified VaR Over Time - 7 Year Rolling Window*

The table shows undiversified industry VaR for the Equity model for each of the nine 7 year rolling window periods. Year 1 contains data for years 1-7. Year 2 contains data for years 2-8 and so on through to year nine which contains data for years 9-15.

| **Industry** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** | **Year 6** | **Year 7** | **Year 8** | **Year 9** |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 0.5417 | 0.5232 | 0.5076 | 0.5084 | 0.5113 | 0.4772 | 0.4745 | 0.4603 | 0.4453 |
| Banks | 0.3030 | 0.3206 | 0.3421 | 0.3622 | 0.3646 | 0.3554 | 0.3525 | 0.3452 | 0.3384 |
| Capital Goods | 0.4591 | 0.4639 | 0.4821 | 0.4965 | 0.4826 | 0.4782 | 0.5614 | 0.4970 | 0.4949 |
| Chemicals | 0.4215 | 0.4263 | 0.4090 | 0.4365 | 0.4599 | 0.4585 | 0.4346 | 0.4272 | 0.4273 |
| Commercial Services & Supplies | 0.5380 | 0.5291 | 0.5763 | 0.6012 | 0.5591 | 0.5074 | 0.4981 | 0.4448 | 0.4355 |
| Construction Materials | 0.4424 | 0.4251 | 0.4403 | 0.4587 | 0.5162 | 0.4924 | 0.4975 | 0.5100 | 0.4895 |
| Consumer Durables & Apparel | 0.5294 | 0.5593 | 0.6159 | 0.6702 | 0.6498 | 0.6767 | 0.4630 | 0.6997 | 0.6425 |
| Diversified Financials | 0.4145 | 0.4273 | 0.4453 | 0.4801 | 0.4871 | 0.4855 | 0.5462 | 0.5382 | 0.4706 |
| Energy | 0.5904 | 0.5904 | 0.5921 | 0.5689 | 0.5608 | 0.5567 | 0.5419 | 0.5520 | 0.5241 |
| Food & Staples Retailing | 0.3727 | 0.3943 | 0.4150 | 0.4361 | 0.4351 | 0.4277 | 0.3722 | 0.3634 | 0.3526 |
| Food Beverage & Tobacco | 0.3987 | 0.4548 | 0.5221 | 0.5823 | 0.5532 | 0.5233 | 0.5476 | 0.5183 | 0.4937 |
| Healthcare Equipment & Services | 0.5246 | 0.5618 | 0.6075 | 0.6302 | 0.6007 | 0.5992 | 0.5862 | 0.5613 | 0.4938 |
| Hotels Restaurants & Leisure | 0.5147 | 0.5517 | 0.5043 | 0.4855 | 0.4855 | 0.5138 | 0.5290 | 0.5397 | 0.4056 |
| Insurance | 0.5366 | 0.5392 | 0.5625 | 0.5650 | 0.4989 | 0.4531 | 0.4777 | 0.4440 | 0.5393 |
| Media | 0.4561 | 0.4676 | 0.4911 | 0.4895 | 0.4711 | 0.4640 | 0.5406 | 0.4720 | 0.4378 |
| Metals & Mining | 0.5595 | 0.5568 | 0.5829 | 0.5812 | 0.5671 | 0.5362 | 0.5900 | 0.5401 | 0.5351 |
| Paper & Forest Products | 0.6713 | 0.6612 | 0.6220 | 0.5584 | 0.5256 | 0.5381 | 0.5485 | 0.6531 | 0.5321 |
| Pharmaceuticals & Biotechnology | 0.6729 | 0.7437 | 0.8295 | 0.9552 | 0.8073 | 0.6368 | 0.7123 | 0.6631 | 0.5726 |
| Real Estate | 0.3931 | 0.4139 | 0.4195 | 0.4179 | 0.4100 | 0.4012 | 0.4295 | 0.3958 | 0.3878 |
| Retailing | 0.5077 | 0.4964 | 0.4578 | 0.5432 | 0.5349 | 0.5144 | 0.4762 | 0.4439 | 0.4273 |
| Software & Services | 0.8412 | 0.9098 | 0.9515 | 1.0290 | 0.9316 | 0.8245 | 1.4855 | 1.5071 | 0.8393 |
| Technology Hardware & Equipment | 0.9514 | 0.8861 | 0.9342 | 0.9973 | 0.9813 | 0.9356 | 0.8689 | 0.8363 | 0.7758 |
| Telecommunication Services | 0.3640 | 0.3821 | 0.4584 | 0.4925 | 0.5090 | 0.5477 | 0.7407 | 0.6555 | 0.7328 |
| Transportation | 0.4732 | 0.4828 | 0.4879 | 0.5184 | 0.5352 | 0.4991 | 0.4628 | 0.4289 | 0.4233 |
| Utilities | 0.3777 | 0.3834 | 0.3948 | 0.4261 | 0.4390 | 0.4622 | 0.4803 | 0.4929 | 0.4561 |
| Portfolio | 0.4516 | 0.4634 | 0.4851 | 0.4990 | 0.4891 | 0.4724 | 0.5023 | 0.4767 | 0.4624 |

We see from Table 4-10 that most of the industries stay fairly constant over time. For example, Banks remain within a band of 0.3 to 0.36 and Energy 0.52 to 0.59. There are some industries which show higher volatility in some years, for example Telecommunication and Consumer Durables show more volatility in earlier years, whilst Commercial Services & Supplies and Pharmaceuticals & Biotechnology show more volatility in latter years. There is no particular window which stands out as having a much higher or lower volatility than other years. In fact there is a very narrow range between the lowest weighted average volatility in year 1 (0.45) and the highest in year 7 (0.50). Table 4-11 shows the significance testing for differences in undiversified VaR over time.

Table 4-11 *Significance Testing - Equity Model Historical Undiversified VaR*

The table shows rankings for the undiversified VaR values shown in Table 4-10. A ranking of 1 (Software and Services in year 8) is the highest risk, and 225 (Banks in year 1) the lowest risk. A Kruskal-Wallis test, as described in Section 3.8.2.2, is applied. The test statistic $K$ must be < the critical value to show no significant difference over time.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 78 | 100 | 113 | 111 | 108 | 144 | 146 | 157 | 168 |
| Banks | 225 | 224 | 222 | 217 | 214 | 218 | 220 | 221 | 223 |
| Capital Goods | 159 | 153 | 139 | 121 | 138 | 142 | 60 | 120 | 123 |
| Chemicals | 193 | 189 | 200 | 177 | 158 | 161 | 181 | 188 | 185 |
| Commercial Services & Supplies | 86 | 94 | 53 | 42 | 65 | 114 | 118 | 170 | 179 |
| Construction Materials | 173 | 191 | 174 | 160 | 104 | 128 | 119 | 109 | 130 |
| Consumer Durables & Apparel | 93 | 64 | 40 | 30 | 35 | 27 | 154 | 26 | 36 |
| Diversified Financials | 197 | 186 | 169 | 141 | 133 | 135 | 75 | 84 | 150 |
| Energy | 47 | 46 | 45 | 55 | 62 | 68 | 77 | 70 | 98 |
| Food & Staples Retailing | 212 | 206 | 196 | 178 | 180 | 184 | 213 | 216 | 219 |
| Food Beverage & Tobacco | 203 | 166 | 101 | 51 | 69 | 99 | 74 | 103 | 125 |
| Healthcare Equipment & Services | 97 | 59 | 41 | 38 | 43 | 44 | 49 | 61 | 124 |
| Hotels Restaurants & Leisure | 105 | 71 | 115 | 134 | 136 | 107 | 95 | 81 | 201 |
| Insurance | 87 | 83 | 58 | 57 | 117 | 167 | 143 | 171 | 82 |
| Media | 165 | 151 | 129 | 131 | 149 | 152 | 79 | 148 | 176 |
| Metals & Mining | 63 | 67 | 50 | 52 | 56 | 88 | 48 | 80 | 90 |
| Paper & Forest Products | 29 | 32 | 39 | 66 | 96 | 85 | 72 | 34 | 92 |
| Pharmaceuticals & Biotechnology | 28 | 22 | 18 | 6 | 20 | 37 | 25 | 31 | 54 |
| Real Estate | 207 | 198 | 194 | 195 | 199 | 202 | 182 | 204 | 208 |
| Retailing | 112 | 122 | 163 | 76 | 91 | 106 | 145 | 172 | 187 |
| Software & Services | 15 | 12 | 7 | 3 | 11 | 19 | 2 | 1 | 16 |
| Technology Hardware & Equipment | 8 | 13 | 10 | 4 | 5 | 9 | 14 | 17 | 21 |
| Telecommunication Services | 215 | 210 | 162 | 127 | 110 | 73 | 23 | 33 | 24 |
| Transportation | 147 | 137 | 132 | 102 | 89 | 116 | 155 | 183 | 192 |
| Utilities | 211 | 209 | 205 | 190 | 175 | 156 | 140 | 126 | 164 |
| ***R*** | 3155 | 3005 | 2775 | 2464 | 2563 | 2781 | 2609 | 2806 | 3267 |
| ***n*** | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| $\sum n$ | 225 | | | | | | | | |
| ***degrees of freedom*** | 8 | | | | | | | | |
| ***K*** | 5.54 | | | | | | | | |
| ***critical value 95%*** | 15.51 | | | ***critical value 99%*** | | | 20.09 | | |
| ***significance*** | - | | | | | | | | |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

For the Equity model, using an undiversified approach, industry VaR shows no significant difference over the 9 time periods.

We have also tested diversified VaR over time. Table 4-12 shows the historical diversified VaR over the 9 periods.

Table 4-12 *Equity Model – Diversified VaR Over Time - 7 Year Rolling Window*

The table shows diversified industry VaR for the Equity model for each of the nine 7 year rolling window periods. Year 1 contains data for years 1-7. Year 2 contains data for years 2-8 and so on through to year nine which contains data for years 9-15.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 0.3010 | 0.2788 | 0.2754 | 0.2946 | 0.3075 | 0.3126 | 0.3262 | 0.3449 | 0.3080 |
| Banks | 0.2231 | 0.2346 | 0.2542 | 0.2754 | 0.2772 | 0.2674 | 0.2688 | 0.2618 | 0.2527 |
| Capital Goods | 0.2369 | 0.2625 | 0.2657 | 0.2878 | 0.2916 | 0.2864 | 0.2631 | 0.2562 | 0.2654 |
| Chemicals | 0.3106 | 0.3026 | 0.2879 | 0.3251 | 0.3337 | 0.2944 | 0.2927 | 0.2959 | 0.2929 |
| Commercial Services & Supplies | 0.2424 | 0.2200 | 0.2423 | 0.2573 | 0.2646 | 0.2762 | 0.2845 | 0.2743 | 0.2677 |
| Construction Materials | 0.3196 | 0.2905 | 0.2851 | 0.2869 | 0.3461 | 0.3165 | 0.3143 | 0.3874 | 0.3704 |
| Consumer Durables & Apparel | 0.3901 | 0.3911 | 0.3339 | 0.3819 | 0.4430 | 0.4549 | 0.2762 | 0.4330 | 0.3886 |
| Diversified Financials | 0.2008 | 0.2032 | 0.1889 | 0.2257 | 0.2243 | 0.2512 | 0.2798 | 0.2603 | 0.2489 |
| Energy | 0.2858 | 0.2548 | 0.2628 | 0.2889 | 0.2994 | 0.2950 | 0.3108 | 0.3006 | 0.2825 |
| Food & Staples Retailing | 0.2459 | 0.2524 | 0.2652 | 0.2977 | 0.3004 | 0.2743 | 0.2968 | 0.2872 | 0.2839 |
| Food Beverage & Tobacco | 0.2022 | 0.2241 | 0.2604 | 0.2959 | 0.2976 | 0.2856 | 0.2966 | 0.2966 | 0.3015 |
| Healthcare Equipment & Services | 0.2273 | 0.2219 | 0.2330 | 0.2568 | 0.2504 | 0.2785 | 0.2880 | 0.2839 | 0.2681 |
| Hotels Restaurants & Leisure | 0.3148 | 0.3126 | 0.2821 | 0.2763 | 0.2777 | 0.2948 | 0.2966 | 0.2943 | 0.3153 |
| Insurance | 0.3376 | 0.3325 | 0.3418 | 0.3400 | 0.3372 | 0.3260 | 0.3358 | 0.3378 | 0.4364 |
| Media | 0.2317 | 0.2299 | 0.2504 | 0.2562 | 0.2605 | 0.2501 | 0.2998 | 0.2491 | 0.2495 |
| Metals & Mining | 0.3382 | 0.3209 | 0.3234 | 0.3205 | 0.3230 | 0.3072 | 0.3176 | 0.2966 | 0.2813 |
| Paper & Forest Products | 0.3612 | 0.3459 | 0.3125 | 0.3056 | 0.3248 | 0.3299 | 0.3241 | 0.4311 | 0.3178 |
| Pharmaceuticals & Biotechnology | 0.3721 | 0.3437 | 0.3376 | 0.3554 | 0.3901 | 0.3909 | 0.3783 | 0.3192 | 0.2857 |
| Real Estate | 0.1850 | 0.1958 | 0.1997 | 0.2188 | 0.2185 | 0.2330 | 0.2145 | 0.1930 | 0.1898 |
| Retailing | 0.2821 | 0.2604 | 0.2306 | 0.3213 | 0.3316 | 0.3459 | 0.3455 | 0.3147 | 0.2907 |
| Software & Services | 0.4353 | 0.4374 | 0.4005 | 0.4326 | 0.4172 | 0.4222 | 1.0487 | 0.9754 | 0.5780 |
| Technology Hardware & Equipment | 0.4857 | 0.3800 | 0.4017 | 0.5278 | 0.6925 | 0.6930 | 0.7745 | 0.7032 | 0.6347 |
| Telecommunication Services | 0.3455 | 0.3597 | 0.4283 | 0.4553 | 0.4836 | 0.5120 | 0.5164 | 0.5163 | 0.6506 |
| Transportation | 0.2438 | 0.2448 | 0.2529 | 0.2808 | 0.2707 | 0.2841 | 0.2769 | 0.2857 | 0.2768 |
| Utilities | 0.2035 | 0.1846 | 0.2060 | 0.2060 | 0.2713 | 0.2805 | 0.3118 | 0.2999 | 0.3158 |
| Portfolio | 0.2675 | 0.2649 | 0.2748 | 0.2917 | 0.2979 | 0.2950 | 0.3050 | 0.2948 | 0.2940 |

The table shows a similar trend to the undiversified VaR shown in Table 4-10 with relatively lower risk, as shown by the weighted average portfolio PD, in years 1 and 2 and highest risk in year 7. Table 4-13 shows the diversified hypothesis testing.

Table 4-13 *Significance Testing - Equity Model Historical Diversified VaR*

The table shows rankings for the diversified VaR values shown in Table 4-12. A ranking of 1 (Software and Services in year 7) is the highest risk, and 225 (Utilities in year 2) the lowest risk. A Kruskal-Wallis test, as described in Section 3.8.2.2, is applied. The test statistic $K$ must be < the critical value to show no significant difference over time.

| **Industry** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** | **Year 6** | **Year 7** | **Year 8** | **Year 9** |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 96 | 144 | 154 | 113 | 91 | 84 | 64 | 49 | 90 |
| Banks | 207 | 197 | 180 | 153 | 147 | 162 | 159 | 170 | 182 |
| Capital Goods | 196 | 169 | 163 | 124 | 118 | 127 | 167 | 178 | 164 |
| Chemicals | 89 | 94 | 123 | 66 | 60 | 114 | 117 | 110 | 116 |
| Commercial Services & Supplies | 194 | 209 | 195 | 175 | 166 | 151 | 133 | 156 | 161 |
| Construction Materials | 74 | 120 | 132 | 126 | 44 | 78 | 83 | 35 | 40 |
| Consumer Durables & Apparel | 33 | 30 | 59 | 36 | 18 | 17 | 152 | 22 | 34 |
| Diversified Financials | 218 | 216 | 223 | 204 | 205 | 184 | 143 | 174 | 190 |
| Energy | 128 | 179 | 168 | 121 | 101 | 111 | 88 | 97 | 137 |
| Food & Staples Retailing | 191 | 183 | 165 | 102 | 98 | 155 | 104 | 125 | 136 |
| Food Beverage & Tobacco | 217 | 206 | 172 | 109 | 103 | 131 | 105 | 108 | 95 |
| Healthcare Equipment & Services | 203 | 208 | 198 | 176 | 186 | 145 | 122 | 135 | 160 |
| Hotels Restaurants & Leisure | 81 | 85 | 138 | 150 | 146 | 112 | 107 | 115 | 80 |
| Insurance | 56 | 61 | 51 | 52 | 57 | 65 | 58 | 54 | 20 |
| Media | 200 | 202 | 185 | 177 | 171 | 187 | 100 | 189 | 188 |
| Metals & Mining | 53 | 72 | 69 | 73 | 70 | 92 | 77 | 106 | 140 |
| Paper & Forest Products | 41 | 46 | 86 | 93 | 67 | 63 | 68 | 24 | 76 |
| Pharmaceuticals & Biotechnology | 39 | 50 | 55 | 43 | 32 | 31 | 38 | 75 | 129 |
| Real Estate | 224 | 220 | 219 | 210 | 211 | 199 | 212 | 221 | 222 |
| Retailing | 139 | 173 | 201 | 71 | 62 | 45 | 47 | 82 | 119 |
| Software & Services | 21 | 19 | 29 | 23 | 27 | 26 | 1 | 2 | 9 |
| Technology Hardware & Equipment | 14 | 37 | 28 | 10 | 6 | 5 | 3 | 4 | 8 |
| Telecommunication Services | 48 | 42 | 25 | 16 | 15 | 13 | 11 | 12 | 7 |
| Transportation | 193 | 192 | 181 | 141 | 158 | 134 | 148 | 130 | 149 |
| Utilities | 215 | 225 | 213 | 214 | 157 | 142 | 87 | 99 | 79 |
| ***R*** | 3170 | 3379 | 3412 | 2778 | 2516 | 2573 | 2394 | 2472 | 2731 |
| ***n*** | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| $\sum n$ | 225 | | | | | | | | |
| ***degrees of freedom*** | 8 | | | | | | | | |
| ***K*** | 11.81 | | | | | | | | |
| ***critical value 95%*** | 15.51 | | | ***critical value 99%*** | | | 20.09 | | |
| ***significance*** | - | | | | | | | | |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

As with undiversified VaR, the test for diversified VaR, using 7 year rolling windows, shows no significant difference over the 9 time periods.

Table 4-14 *Structural Model – Undiversified PD Over Time Using a 7 Year Rolling Window*

The table shows undiversified industry calibrated PD (per methodology in section 3.4.2) for the Structural model for each of the nine 7 year rolling window periods. Year 1 contains data for years 1-7. Year 2 contains data for years 2-8 and so on through to year nine which contains data for years 9-15.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 0.0163 | 0.0145 | 0.0105 | 0.0106 | 0.0107 | 0.0106 | 0.0108 | 0.0070 | 0.0068 |
| Banks | 0.0044 | 0.0063 | 0.0084 | 0.0089 | 0.0079 | 0.0068 | 0.0070 | 0.0056 | 0.0050 |
| Capital Goods | 0.0039 | 0.0041 | 0.0056 | 0.0061 | 0.0058 | 0.0046 | 0.0057 | 0.0053 | 0.0057 |
| Chemicals | 0.0031 | 0.0036 | 0.0024 | 0.0033 | 0.0068 | 0.0074 | 0.0071 | 0.0037 | 0.0034 |
| Commercial Services & Supplies | 0.0057 | 0.0044 | 0.0085 | 0.0103 | 0.0068 | 0.0037 | 0.0025 | 0.0019 | 0.0018 |
| Construction Materials | 0.0009 | 0.0005 | 0.0008 | 0.0012 | 0.0033 | 0.0028 | 0.0061 | 0.0028 | 0.0028 |
| Consumer Durables & Apparel | 0.0024 | 0.0030 | 0.0065 | 0.0116 | 0.0100 | 0.0062 | 0.0006 | 0.0229 | 0.0167 |
| Diversified Financials | 0.0005 | 0.0005 | 0.0008 | 0.0013 | 0.0013 | 0.0006 | 0.0008 | 0.0009 | 0.0010 |
| Energy | 0.0021 | 0.0022 | 0.0030 | 0.0031 | 0.0025 | 0.0019 | 0.0020 | 0.0019 | 0.0018 |
| Food & Staples Retailing | 0.0015 | 0.0022 | 0.0035 | 0.0044 | 0.0043 | 0.0030 | 0.0020 | 0.0017 | 0.0015 |
| Food Beverage & Tobacco | 0.0022 | 0.0035 | 0.0060 | 0.0075 | 0.0070 | 0.0062 | 0.0072 | 0.0071 | 0.0082 |
| Healthcare Equipment & Services | 0.0031 | 0.0042 | 0.0057 | 0.0076 | 0.0071 | 0.0055 | 0.0059 | 0.0054 | 0.0068 |
| Hotels Restaurants & Leisure | 0.0024 | 0.0045 | 0.0028 | 0.0033 | 0.0029 | 0.0032 | 0.0030 | 0.0033 | 0.0007 |
| Insurance | 0.0422 | 0.0460 | 0.0475 | 0.0498 | 0.0415 | 0.0368 | 0.0464 | 0.0533 | 0.0745 |
| Media | 0.0016 | 0.0018 | 0.0025 | 0.0030 | 0.0040 | 0.0030 | 0.0050 | 0.0039 | 0.0025 |
| Metals & Mining | 0.0038 | 0.0039 | 0.0052 | 0.0059 | 0.0061 | 0.0041 | 0.0040 | 0.0023 | 0.0017 |
| Paper & Forest Products | 0.0172 | 0.0168 | 0.0108 | 0.0079 | 0.0075 | 0.0080 | 0.0079 | 0.0082 | 0.0065 |
| Pharmaceuticals & Biotechnology | 0.0062 | 0.0076 | 0.0109 | 0.0149 | 0.0125 | 0.0047 | 0.0044 | 0.0039 | 0.0037 |
| Real Estate | 0.0005 | 0.0008 | 0.0009 | 0.0011 | 0.0012 | 0.0011 | 0.0013 | 0.0010 | 0.0011 |
| Retailing | 0.0083 | 0.0073 | 0.0019 | 0.0089 | 0.0080 | 0.0059 | 0.0045 | 0.0024 | 0.0019 |
| Software & Services | 0.0176 | 0.0196 | 0.0232 | 0.0290 | 0.0195 | 0.0090 | 0.0227 | 0.0182 | 0.0068 |
| Technology Hardware & Equipment | 0.0295 | 0.0330 | 0.0404 | 0.0632 | 0.0682 | 0.0569 | 0.0475 | 0.0391 | 0.0438 |
| Telecommunication Services | 0.0022 | 0.0020 | 0.0038 | 0.0054 | 0.0064 | 0.0081 | 0.0071 | 0.0003 | 0.0060 |
| Transportation | 0.0043 | 0.0040 | 0.0047 | 0.0063 | 0.0070 | 0.0057 | 0.0041 | 0.0024 | 0.0028 |
| Utilities | 0.0001 | 0.0001 | 0.0005 | 0.0006 | 0.0007 | 0.0015 | 0.0015 | 0.0015 | 0.0011 |
| Portfolio | 0.0063 | 0.0076 | 0.0091 | 0.0099 | 0.0089 | 0.0075 | 0.0083 | 0.0076 | 0.0088 |

The Structural model shows a somewhat greater difference over time than the Equity model. The lowest weighted average portfolio PD in year 1 is 0.63%, with the highest in year 4 being 0.99%.

Significance testing is shown in Table 4-15.

Table 4-15 *Significance Testing - Structural Model Historical Undiversified PD*

The table shows rankings for the undiversified PD values shown in Table 4-14. A ranking of 1 (Insurance in year 9) is the highest risk, and 225 (Utilities in year 2) the lowest risk. A Kruskal-Wallis test, as described in Section 3.8.2.2, is applied. The test statistic $K$ must be < the critical value to show significant association in rankings.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 30 | 32 | 41 | 39 | 38 | 40 | 36 | 72 | 74 |
| Banks | 117 | 82 | 48 | 45 | 55 | 73 | 70 | 102 | 108 |
| Capital Goods | 131 | 122 | 101 | 87 | 95 | 112 | 99 | 106 | 96 |
| Chemicals | 147 | 137 | 166 | 144 | 78 | 62 | 66 | 136 | 140 |
| Commercial Services & Supplies | 97 | 116 | 47 | 42 | 76 | 134 | 164 | 179 | 185 |
| Construction Materials | 207 | 221 | 209 | 199 | 142 | 158 | 89 | 160 | 156 |
| Consumer Durables & Apparel | 167 | 149 | 79 | 34 | 43 | 86 | 217 | 21 | 29 |
| Diversified Financials | 220 | 219 | 211 | 197 | 195 | 215 | 212 | 208 | 205 |
| Energy | 175 | 172 | 152 | 146 | 163 | 181 | 177 | 182 | 184 |
| Food & Staples Retailing | 192 | 174 | 138 | 118 | 119 | 154 | 176 | 188 | 194 |
| Food Beverage & Tobacco | 173 | 139 | 90 | 60 | 69 | 85 | 64 | 67 | 50 |
| Healthcare Equipment & Services | 148 | 121 | 100 | 59 | 65 | 103 | 94 | 104 | 77 |
| Hotels Restaurants & Leisure | 168 | 113 | 157 | 141 | 155 | 145 | 153 | 143 | 213 |
| Insurance | 12 | 10 | 8 | 6 | 13 | 16 | 9 | 5 | 1 |
| Media | 189 | 186 | 161 | 150 | 127 | 151 | 109 | 130 | 162 |
| Metals & Mining | 132 | 128 | 107 | 92 | 88 | 123 | 126 | 170 | 187 |
| Paper & Forest Products | 27 | 28 | 37 | 57 | 61 | 53 | 56 | 51 | 80 |
| Pharmaceuticals & Biotechnology | 84 | 58 | 35 | 31 | 33 | 110 | 115 | 129 | 135 |
| Real Estate | 218 | 210 | 206 | 201 | 198 | 203 | 196 | 204 | 202 |
| Retailing | 49 | 63 | 180 | 46 | 54 | 93 | 114 | 169 | 183 |
| Software & Services | 26 | 23 | 20 | 19 | 24 | 44 | 22 | 25 | 75 |
| Technology Hardware & Equipment | 18 | 17 | 14 | 3 | 2 | 4 | 7 | 15 | 11 |
| Telecommunication Services | 171 | 178 | 133 | 105 | 81 | 52 | 68 | 223 | 91 |
| Transportation | 120 | 125 | 111 | 83 | 71 | 98 | 124 | 165 | 159 |
| Utilities | 224 | 225 | 222 | 216 | 214 | 190 | 191 | 193 | 200 |
| ***R*** | 3242 | 3048 | 2773 | 2320 | 2259 | 2685 | 2754 | 3147 | 3197 |
| ***n*** | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| $\sum n$ | 225 | | | | | | | | |
| ***degrees of freedom*** | 8 | | | | | | | | |
| ***K*** | 10.09 | | | | | | | | |
| ***critical value 95%*** | 15.51 | | | ***critical value 99%*** | | | 20.09 | | |
| ***significance*** | - | | | | | | | | |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

For the Structural model, using undiversified PD and a 7 year rolling window approach, there is no significant difference in industry rankings over time.

We have also modelled diversified PD over time for the Structural model, with the results shown in Table 4-16.

Table 4-16 *Structural Model – Diversified PD Over Time Using a 7 Year Rolling Window*

The table shows Diversified industry PD for the Structural model for each of the nine 7 year rolling window periods. Year 1 contains data for years 1-7. Year 2 contains data for years 2-8 and so on through to year nine which contains data for years 9-15.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 0.00116 | 0.00071 | 0.00026 | 0.00041 | 0.00071 | 0.00112 | 0.00182 | 0.00118 | 0.00143 |
| Banks | 0.00067 | 0.00118 | 0.00194 | 0.00240 | 0.00202 | 0.00158 | 0.00172 | 0.00128 | 0.00096 |
| Capital Goods | 0.00001 | 0.00004 | 0.00009 | 0.00016 | 0.00015 | 0.00010 | 0.00002 | 0.00002 | 0.00006 |
| Chemicals | 0.00038 | 0.00038 | 0.00016 | 0.00046 | 0.00121 | 0.00080 | 0.00066 | 0.00028 | 0.00025 |
| Commercial Services & Supplies | 0.00001 | 0.00000 | 0.00001 | 0.00003 | 0.00001 | 0.00001 | 0.00001 | 0.00002 | 0.00002 |
| Construction Materials | 0.00004 | 0.00001 | 0.00001 | 0.00001 | 0.00017 | 0.00009 | 0.00032 | 0.00044 | 0.00042 |
| Consumer Durables & Apparel | 0.00025 | 0.00030 | 0.00015 | 0.00050 | 0.00115 | 0.00046 | 0.00000 | 0.00470 | 0.00215 |
| Diversified Financials | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| Energy | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00001 | 0.00000 | 0.00000 |
| Food & Staples Retailing | 0.00003 | 0.00006 | 0.00013 | 0.00032 | 0.00035 | 0.00009 | 0.00036 | 0.00029 | 0.00026 |
| Food Beverage & Tobacco | 0.00000 | 0.00000 | 0.00003 | 0.00007 | 0.00008 | 0.00007 | 0.00012 | 0.00014 | 0.00037 |
| Healthcare Equipment & Services | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00001 | 0.00001 | 0.00002 | 0.00008 |
| Hotels Restaurants & Leisure | 0.00003 | 0.00007 | 0.00002 | 0.00003 | 0.00002 | 0.00003 | 0.00002 | 0.00002 | 0.00003 |
| Insurance | 0.01590 | 0.01786 | 0.01809 | 0.01935 | 0.01637 | 0.01737 | 0.02483 | 0.03590 | 0.06114 |
| Media | 0.00000 | 0.00000 | 0.00000 | 0.00001 | 0.00003 | 0.00001 | 0.00006 | 0.00002 | 0.00002 |
| Metals & Mining | 0.00009 | 0.00007 | 0.00008 | 0.00009 | 0.00013 | 0.00005 | 0.00003 | 0.00001 | 0.00000 |
| Paper & Forest Products | 0.00109 | 0.00084 | 0.00019 | 0.00012 | 0.00023 | 0.00042 | 0.00037 | 0.00076 | 0.00033 |
| Pharmaceuticals & Biotechnology | 0.00010 | 0.00002 | 0.00002 | 0.00002 | 0.00010 | 0.00006 | 0.00004 | 0.00000 | 0.00000 |
| Real Estate | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| Retailing | 0.00021 | 0.00013 | 0.00000 | 0.00043 | 0.00049 | 0.00044 | 0.00050 | 0.00021 | 0.00006 |
| Software & Services | 0.00084 | 0.00082 | 0.00054 | 0.00092 | 0.00031 | 0.00008 | 0.00676 | 0.00423 | 0.00109 |
| Technology Hardware & Equipment | 0.00295 | 0.00161 | 0.00326 | 0.02176 | 0.04020 | 0.03441 | 0.03618 | 0.02939 | 0.03791 |
| Telecommunication Services | 0.00150 | 0.00130 | 0.00254 | 0.00328 | 0.00471 | 0.00571 | 0.00119 | 0.00002 | 0.00293 |
| Transportation | 0.00002 | 0.00001 | 0.00002 | 0.00008 | 0.00004 | 0.00012 | 0.00007 | 0.00006 | 0.00017 |
| Utilities | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00001 | 0.00003 | 0.00001 | 0.00002 |
| Portfolio | 0.0015 | 0.0019 | 0.0023 | 0.0027 | 0.0023 | 0.0022 | 0.0027 | 0.0032 | 0.0048 |

Significance testing in Table 4-17 shows that there is no significant difference in rankings over time, hence no significant change has been brought about by diversification.

For the Structural model, using undiversified PD and a 7 year rolling window approach, we therefore accept there is association in industry rankings over time.

Table 4-17 *Significance Testing - Structural Model Historical Diversified PD*

The table shows rankings for the diversified PD values shown in Table 4-16. A ranking of 1 (Insurance in year 9) is the highest risk, and 225 (Utilities in year 2) the lowest risk. A Kruskal-Wallis test, as described in Section 3.8.2.2, is applied. The test statistic $K$ must be < the critical value to show no significant difference over time.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 42 | 54 | 84 | 69 | 55 | 44 | 30 | 41 | 35 |
| Banks | 56 | 40 | 29 | 26 | 28 | 33 | 31 | 37 | 47 |
| Capital Goods | 168 | 131 | 110 | 93 | 95 | 104 | 148 | 144 | 122 |
| Chemicals | 71 | 70 | 94 | 63 | 38 | 52 | 57 | 82 | 86 |
| Commercial Services & Supplies | 176 | 196 | 164 | 140 | 165 | 163 | 162 | 153 | 143 |
| Construction Materials | 129 | 177 | 173 | 170 | 91 | 108 | 77 | 64 | 68 |
| Consumer Durables & Apparel | 85 | 80 | 96 | 59 | 43 | 62 | 193 | 19 | 27 |
| Diversified Financials | 222 | 220 | 216 | 215 | 213 | 221 | 207 | 211 | 201 |
| Energy | 200 | 212 | 203 | 184 | 179 | 189 | 172 | 183 | 188 |
| Food & Staples Retailing | 133 | 126 | 100 | 78 | 75 | 109 | 74 | 81 | 83 |
| Food Beverage & Tobacco | 192 | 182 | 138 | 119 | 115 | 117 | 103 | 97 | 73 |
| Healthcare Equipment & Services | 205 | 208 | 206 | 186 | 185 | 178 | 161 | 145 | 114 |
| Hotels Restaurants & Leisure | 135 | 121 | 152 | 136 | 147 | 137 | 156 | 160 | 134 |
| Insurance | 15 | 12 | 11 | 10 | 14 | 13 | 8 | 5 | 1 |
| Media | 199 | 198 | 187 | 175 | 141 | 167 | 125 | 149 | 150 |
| Metals & Mining | 111 | 120 | 113 | 107 | 98 | 128 | 142 | 174 | 191 |
| Paper & Forest Products | 45 | 49 | 90 | 102 | 87 | 67 | 72 | 53 | 76 |
| Pharmaceuticals & Biotechnology | 106 | 151 | 158 | 154 | 105 | 127 | 132 | 180 | 181 |
| Real Estate | 223 | 218 | 214 | 204 | 197 | 194 | 202 | 209 | 210 |
| Retailing | 89 | 99 | 195 | 66 | 61 | 65 | 60 | 88 | 124 |
| Software & Services | 50 | 51 | 58 | 48 | 79 | 116 | 16 | 20 | 46 |
| Technology Hardware & Equipment | 23 | 32 | 22 | 9 | 2 | 6 | 4 | 7 | 3 |
| Telecommunication Services | 34 | 36 | 25 | 21 | 18 | 17 | 39 | 155 | 24 |
| Transportation | 159 | 171 | 157 | 112 | 130 | 101 | 118 | 123 | 92 |
| Utilities | 224 | 225 | 217 | 219 | 190 | 166 | 139 | 169 | 146 |
| ***R*** | 3092 | 3179 | 3212 | 2765 | 2551 | 2684 | 2628 | 2749 | 2565 |
| ***n*** | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| $\sum n$ | 225 | | | | | | | | |
| ***degrees of freedom*** | 8 | | | | | | | | |
| ***K*** | 5.26 | | | | | | | | |
| ***critical value 95%*** | 15.51 | | | ***critical value 99%*** | | | 20.09 | | |
| ***significance*** | - | | | | | | | | |

* denotes significance at the 95% confidence level

** denotes significance at the 99% confidence level

As both the Equity and Structural models have shown no significant difference over time, using diversified and undiversified approaches, for the 7 year rolling window approach, we accept the null hypothesis that industry VaR stays constant over time.

As mentioned in Section 3.3.1.1, the seven year rolling window approach could be a key factor in influencing the stability in VaR over time, as there is overlap on the data with this approach. Year 1 contains 6 of the same years as year 2, year 2 contains 6 of the same years 3 and so on. To assess the impact of this, we have also tested historical VaR for both the Equity and Structural models using 12 month periods. The outcome of this is shown in Table 4-18 through to Table 4-21.

Table 4-18 *Equity Model Historical VaR using 12 Month Data Windows*

The table shows undiversified VaR over time for the equity model for each industry over nine 1 year periods, i.e. each year contains only the last 12 months data.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 0.5660 | 0.5956 | 0.3913 | 0.4227 | 0.5943 | 0.5276 | 0.5440 | 0.4515 | 0.5093 |
| Banks | 0.2439 | 0.2231 | 0.2387 | 0.3163 | 0.3506 | 0.3588 | 0.3620 | 0.3709 | 0.3785 |
| Capital Goods | 0.3787 | 0.3775 | 0.3711 | 0.4980 | 0.4816 | 0.5460 | 0.5896 | 0.4580 | 0.4932 |
| Chemicals | 0.4000 | 0.4106 | 0.3030 | 0.4108 | 0.5324 | 0.4911 | 0.4606 | 0.4107 | 0.4515 |
| Commercial Services & Supplies | 0.4307 | 0.4084 | 0.4386 | 0.6297 | 0.5698 | 0.5393 | 0.5973 | 0.4648 | 0.4986 |
| Construction Materials | 0.4804 | 0.3855 | 0.3992 | 0.3938 | 0.5390 | 0.5096 | 0.5342 | 0.5718 | 0.5968 |
| Consumer Durables & Apparel | 0.4278 | 0.4819 | 0.3696 | 0.6513 | 0.6302 | 0.6748 | 0.4603 | 0.5344 | 0.5733 |
| Diversified Financials | 0.4126 | 0.3434 | 0.3004 | 0.3842 | 0.4190 | 0.3782 | 0.5238 | 0.5093 | 0.4850 |
| Energy | 0.5647 | 0.5411 | 0.4356 | 0.4795 | 0.4911 | 0.5356 | 0.6188 | 0.5970 | 0.5617 |
| Food & Staples Retailing | 0.2886 | 0.2919 | 0.2382 | 0.3359 | 0.4519 | 0.4923 | 0.4114 | 0.3951 | 0.4072 |
| Food Beverage & Tobacco | 0.3554 | 0.3490 | 0.2842 | 0.3503 | 0.3728 | 0.4576 | 0.5026 | 0.5636 | 0.6597 |
| Healthcare Equipment & Services | 0.4614 | 0.4405 | 0.4601 | 0.5392 | 0.6170 | 0.5719 | 0.5830 | 0.5679 | 0.5129 |
| Hotels Restaurants & Leisure | 0.3567 | 0.4369 | 0.4212 | 0.4873 | 0.4446 | 0.4740 | 0.5937 | 0.6012 | 0.4261 |
| Insurance | 0.3493 | 0.3566 | 0.4143 | 0.5542 | 0.6270 | 0.4051 | 0.5228 | 0.3938 | 0.5728 |
| Media | 0.3545 | 0.3514 | 0.3411 | 0.4357 | 0.4415 | 0.4612 | 0.6577 | 0.4856 | 0.4311 |
| Metals & Mining | 0.5730 | 0.4394 | 0.4641 | 0.4957 | 0.6042 | 0.5218 | 0.6255 | 0.6545 | 0.6709 |
| Paper & Forest Products | 0.5372 | 0.5809 | 0.4705 | 0.3982 | 0.4824 | 0.6036 | 0.6015 | 0.6815 | 0.5770 |
| Pharmaceuticals & Biotechnology | 0.5491 | 0.5847 | 0.5905 | 0.9098 | 0.8307 | 0.7079 | 0.8229 | 0.8008 | 0.5872 |
| Real Estate | 0.2823 | 0.2945 | 0.2904 | 0.3374 | 0.3587 | 0.4495 | 0.4622 | 0.4270 | 0.4312 |
| Retailing | 0.4948 | 0.4515 | 0.3715 | 0.5082 | 0.5835 | 0.5670 | 0.6035 | 0.5276 | 0.4845 |
| Software & Services | 0.5257 | 0.6471 | 0.5947 | 0.8394 | 0.9397 | 0.8152 | 1.2598 | 1.6003 | 0.8830 |
| Technology Hardware & Equipment | 0.8440 | 0.6526 | 0.7582 | 1.1482 | 1.2236 | 1.2408 | 1.0945 | 0.9587 | 0.8250 |
| Telecommunication Services | 0.3355 | 0.2447 | 0.2563 | 0.3352 | 0.3783 | 0.4965 | 0.8259 | 0.5483 | 0.7500 |
| Transportation | 0.4009 | 0.4037 | 0.3366 | 0.4893 | 0.5449 | 0.5948 | 0.5507 | 0.4445 | 0.4458 |
| Utilities | 0.3556 | 0.3457 | 0.3028 | 0.3527 | 0.3954 | 0.4883 | 0.5498 | 0.4952 | 0.4774 |
| Portfolio | 0.3943 | 0.3580 | 0.3507 | 0.4297 | 0.4780 | 0.4734 | 0.5394 | 0.5091 | 0.5187 |

We now see a greater variance in VaR over time. For example Banks, which had a very narrow VaR range over time, now show a range from 22% in year 1 to 38% in year 9. The weighted portfolio average is 35% in year 3 compared to 54% in year 7. We also see some changes to the ranking order. For example, on the 7 year approach, Chemicals in year 5 had a more favourable VaR than Capital Goods and in year 7

Media had a more favourable VaR than Metals. These positions are reversed under the 1 year approach.

Table 4-19 *Significance Testing - Equity Model Historical Undiversified VaR Using 12 Month Data Windows*

The table shows rankings for the 1 year undiversified VaR values shown in Table 4-18. A ranking of 1 (Software and Services in year 8) is the highest risk, and 225 (Banks in year 2) the lowest risk. A Kruskal-Wallis test, as described in Section 3.8.2.2, is applied. The test statistic $K$ must be < the critical value to show no significant difference in rankings.

| **Industry** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** | **Year 6** | **Year 7** | **Year 8** | **Year 9** |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 66 | 45 | 175 | 154 | 48 | 88 | 77 | 135 | 96 |
| Banks | 222 | 225 | 223 | 210 | 198 | 189 | 188 | 186 | 179 |
| Capital Goods | 178 | 182 | 185 | 100 | 117 | 75 | 51 | 131 | 105 |
| Chemicals | 168 | 162 | 211 | 160 | 86 | 108 | 128 | 161 | 136 |
| Commercial Services & Supplies | 150 | 163 | 144 | 32 | 63 | 79 | 42 | 123 | 99 |
| Construction Materials | 118 | 176 | 169 | 173 | 81 | 94 | 85 | 62 | 44 |
| Consumer Durables & Apparel | 151 | 116 | 187 | 29 | 31 | 23 | 129 | 84 | 58 |
| Diversified Financials | 158 | 203 | 213 | 177 | 156 | 181 | 90 | 95 | 113 |
| Energy | 67 | 78 | 147 | 119 | 107 | 83 | 35 | 43 | 69 |
| Food & Staples Retailing | 217 | 215 | 224 | 207 | 133 | 106 | 159 | 172 | 164 |
| Food Beverage & Tobacco | 194 | 201 | 218 | 199 | 183 | 132 | 98 | 68 | 25 |
| Healthcare Equipment & Services | 126 | 142 | 130 | 80 | 36 | 61 | 55 | 64 | 93 |
| Hotels Restaurants & Leisure | 191 | 145 | 155 | 111 | 139 | 121 | 49 | 41 | 153 |
| Insurance | 200 | 192 | 157 | 70 | 33 | 165 | 91 | 174 | 60 |
| Media | 195 | 197 | 204 | 146 | 141 | 127 | 26 | 112 | 149 |
| Metals & Mining | 59 | 143 | 124 | 102 | 37 | 92 | 34 | 27 | 24 |
| Paper & Forest Products | 82 | 56 | 122 | 170 | 115 | 38 | 40 | 22 | 57 |
| Pharmaceuticals & Biotechnology | 73 | 53 | 50 | 9 | 13 | 21 | 16 | 18 | 52 |
| Real Estate | 219 | 214 | 216 | 205 | 190 | 137 | 125 | 152 | 148 |
| Retailing | 104 | 134 | 184 | 97 | 54 | 65 | 39 | 87 | 114 |
| Software & Services | 89 | 30 | 47 | 12 | 8 | 17 | 2 | 1 | 10 |
| Technology Hardware & Equipment | 11 | 28 | 19 | 5 | 4 | 3 | 6 | 7 | 15 |
| Telecommunication Services | 208 | 221 | 220 | 209 | 180 | 101 | 14 | 74 | 20 |
| Transportation | 167 | 166 | 206 | 109 | 76 | 46 | 71 | 140 | 138 |
| Utilities | 193 | 202 | 212 | 196 | 171 | 110 | 72 | 103 | 120 |
| ***R*** | 3606 | 3689 | 4142 | 3081 | 2400 | 2262 | 1722 | 2282 | 2241 |
| ***n*** | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| **$\sum n$** | 225 | | | | | | | | |
| ***degrees of freedom*** | 8 | | | | | | | | |
| ***K*** | 51.98 | | | | | | | | |
| ***critical value 95%*** | 15.51 | | | ***critical value 99%*** | | | 20.09 | | |
| ***significance*** | ** | | | | | | | | |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

The significance testing in Table 4-19 shows that for the Equity model, using 12 month data windows, there is no association in industry VaR over the 9 time periods.

Table 4-20 *Structural Model Historical PD Using 12 Month Data Windows*

The table shows undiversified PD over time for the Structural model for each industry over nine 1 year periods, i.e. each year contains only the last 12 months data.

| **Industry** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** | **Year 6** | **Year 7** | **Year 8** | **Year 9** |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 0.0181 | 0.0249 | 0.0035 | 0.0033 | 0.0118 | 0.0154 | 0.0200 | 0.0053 | 0.0134 |
| Banks | 0.0014 | 0.0006 | 0.0017 | 0.0044 | 0.0060 | 0.0091 | 0.0065 | 0.0099 | 0.0095 |
| Capital Goods | 0.0014 | 0.0013 | 0.0013 | 0.0055 | 0.0057 | 0.0077 | 0.0083 | 0.0052 | 0.0078 |
| Chemicals | 0.0023 | 0.0029 | 0.0002 | 0.0017 | 0.0093 | 0.0102 | 0.0097 | 0.0033 | 0.0048 |
| Commercial Services & Supplies | 0.0018 | 0.0009 | 0.0021 | 0.0123 | 0.0077 | 0.0055 | 0.0059 | 0.0024 | 0.0038 |
| Construction Materials | 0.0019 | 0.0002 | 0.0004 | 0.0003 | 0.0037 | 0.0028 | 0.0082 | 0.0046 | 0.0079 |
| Consumer Durables & Apparel | 0.0007 | 0.0015 | 0.0002 | 0.0096 | 0.0081 | 0.0060 | 0.0005 | 0.0104 | 0.0150 |
| Diversified Financials | 0.0004 | 0.0000 | 0.0000 | 0.0001 | 0.0007 | 0.0000 | 0.0007 | 0.0005 | 0.0011 |
| Energy | 0.0017 | 0.0011 | 0.0003 | 0.0010 | 0.0011 | 0.0016 | 0.0037 | 0.0030 | 0.0030 |
| Food & Staples Retailing | 0.0002 | 0.0002 | 0.0000 | 0.0009 | 0.0057 | 0.0050 | 0.0034 | 0.0028 | 0.0035 |
| Food Beverage & Tobacco | 0.0012 | 0.0007 | 0.0000 | 0.0002 | 0.0005 | 0.0025 | 0.0045 | 0.0088 | 0.0217 |
| Healthcare Equipment & Services | 0.0019 | 0.0010 | 0.0013 | 0.0033 | 0.0080 | 0.0042 | 0.0058 | 0.0052 | 0.0075 |
| Hotels Restaurants & Leisure | 0.0002 | 0.0012 | 0.0007 | 0.0039 | 0.0016 | 0.0027 | 0.0057 | 0.0053 | 0.0010 |
| Insurance | 0.0144 | 0.0179 | 0.0207 | 0.0607 | 0.0605 | 0.0322 | 0.0478 | 0.0478 | 0.0787 |
| Media | 0.0002 | 0.0002 | 0.0001 | 0.0010 | 0.0032 | 0.0033 | 0.0109 | 0.0048 | 0.0031 |
| Metals & Mining | 0.0041 | 0.0009 | 0.0014 | 0.0026 | 0.0078 | 0.0039 | 0.0055 | 0.0055 | 0.0058 |
| Paper & Forest Products | 0.0079 | 0.0119 | 0.0021 | 0.0008 | 0.0047 | 0.0116 | 0.0110 | 0.0095 | 0.0098 |
| Pharmaceuticals & Biotechnology | 0.0020 | 0.0022 | 0.0021 | 0.0127 | 0.0121 | 0.0069 | 0.0078 | 0.0085 | 0.0043 |
| Real Estate | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0006 | 0.0022 | 0.0018 | 0.0020 | 0.0025 |
| Retailing | 0.0075 | 0.0052 | 0.0004 | 0.0068 | 0.0113 | 0.0096 | 0.0112 | 0.0063 | 0.0034 |
| Software & Services | 0.0026 | 0.0060 | 0.0047 | 0.0158 | 0.0198 | 0.0103 | 0.0186 | 0.0148 | 0.0090 |
| Technology Hardware & Equipment | 0.0233 | 0.0165 | 0.0262 | 0.0721 | 0.0842 | 0.0865 | 0.0656 | 0.0250 | 0.0474 |
| Telecommunication Services | 0.0012 | 0.0000 | 0.0000 | 0.0004 | 0.0015 | 0.0080 | 0.0133 | 0.0001 | 0.0068 |
| Transportation | 0.0024 | 0.0017 | 0.0005 | 0.0052 | 0.0076 | 0.0107 | 0.0082 | 0.0023 | 0.0035 |
| Utilities | 0.0001 | 0.0000 | 0.0000 | 0.0001 | 0.0003 | 0.0029 | 0.0030 | 0.0014 | 0.0015 |
| Portfolio | 0.0024 | 0.0019 | 0.0026 | 0.0074 | 0.0091 | 0.0086 | 0.0089 | 0.0099 | 0.0123 |

The Structural model shows a very similar pattern to the Equity model, with a broader range of portfolio PD outcomes over time and a shift in some rankings, for example Chemicals having a better ranking than Commercial Services and Supplies in year 1 using a 7 year window as per Table 4-15, but the position is reversed using a 1 year window per Table 4-21.

Table 4-21 *Significance Testing - Structural Model Historical PD Using 12 Month Data Windows*

The table shows rankings for the 1 year undiversified PD values shown in Table 4-20. A ranking of 1 (Technology Hardware & Equipment in year 6) is the highest risk, and 225 (Utilities in year 2) the lowest risk. A Kruskal-Wallis test, as described in Section 3.8.2.2, is applied. The test statistic $K$ must be < the critical value to show significant association over the 9 time periods.

| **Industry** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** | **Year 6** | **Year 7** | **Year 8** | **Year 9** |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 21 | 14 | 114 | 118 | 35 | 25 | 18 | 92 | 29 |
| Banks | 163 | 186 | 152 | 104 | 79 | 53 | 76 | 45 | 51 |
| Capital Goods | 162 | 165 | 164 | 90 | 84 | 69 | 57 | 94 | 65 |
| Chemicals | 138 | 127 | 202 | 151 | 52 | 44 | 47 | 120 | 99 |
| Commercial Services & Supplies | 149 | 177 | 142 | 32 | 68 | 88 | 81 | 136 | 110 |
| Construction Materials | 148 | 203 | 195 | 196 | 111 | 130 | 58 | 102 | 63 |
| Consumer Durables & Apparel | 182 | 158 | 199 | 48 | 60 | 78 | 188 | 42 | 26 |
| Diversified Financials | 193 | 218 | 224 | 211 | 183 | 216 | 184 | 191 | 171 |
| Energy | 153 | 170 | 197 | 174 | 172 | 155 | 112 | 125 | 126 |
| Food & Staples Retailing | 205 | 201 | 220 | 179 | 85 | 97 | 116 | 129 | 113 |
| Food Beverage & Tobacco | 169 | 185 | 214 | 204 | 190 | 134 | 103 | 55 | 16 |
| Healthcare Equipment & Services | 147 | 176 | 166 | 121 | 62 | 106 | 83 | 96 | 72 |
| Hotels Restaurants & Leisure | 208 | 168 | 181 | 109 | 156 | 131 | 86 | 91 | 175 |
| Insurance | 28 | 22 | 17 | 6 | 7 | 11 | 8 | 9 | 3 |
| Media | 200 | 207 | 209 | 173 | 122 | 119 | 40 | 98 | 123 |
| Metals & Mining | 107 | 178 | 160 | 132 | 67 | 108 | 89 | 87 | 82 |
| Paper & Forest Products | 64 | 34 | 143 | 180 | 100 | 36 | 39 | 50 | 46 |
| Pharmaceuticals & Biotechnology | 145 | 140 | 144 | 31 | 33 | 73 | 66 | 56 | 105 |
| Real Estate | 223 | 215 | 222 | 206 | 187 | 141 | 150 | 146 | 135 |
| Retailing | 71 | 93 | 192 | 74 | 37 | 49 | 38 | 77 | 117 |
| Software & Services | 133 | 80 | 101 | 24 | 19 | 43 | 20 | 27 | 54 |
| Technology Hardware & Equipment | 15 | 23 | 12 | 4 | 2 | 1 | 5 | 13 | 10 |
| Telecommunication Services | 167 | 221 | 219 | 194 | 159 | 61 | 30 | 210 | 75 |
| Transportation | 137 | 154 | 189 | 95 | 70 | 41 | 59 | 139 | 115 |
| Utilities | 213 | 225 | 217 | 212 | 198 | 128 | 124 | 161 | 157 |
| ***R*** | 3541 | 3740 | 4195 | 3068 | 2338 | 2137 | 1877 | 2391 | 2138 |
| ***n*** | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| $\sum n$ | 225 | | | | | | | | |
| ***degrees of freedom*** | 8 | | | | | | | | |
| ***K*** | 52.44 | | | | | | | | |
| ***critical value 95%*** | 15.51 | | | ***critical value 99%*** | | | 20.09 | | |
| ***significance*** | ** | | | | | | | | |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

Significant differences over time have been found for both the Equity and Structural models using 1 year windows. Thus, for the 1 year window approach, we reject the null hypothesis that industry VaR stays constant over time for both these models.

The fact that the 7 year window approach gives a different outcome to the 1 year approach has significant implications for users of VaR methodology such as Banks. Whilst using longer periods of data has some advantages, such as taking account of different business cycles, it is also important to focus on the risks associated with shorter time intervals. Using longer periods tends to smooth out the peaks and the troughs, and the current risks (e.g. those seen over the past year) may be different to the 'average' experienced over a longer window. Using longer periods for VaR may not sufficient identify the highest risk. In this respect CVaR, which focuses on the extreme risks, is important.

### 4.4.3. *$H_3$:There is association between diversified VaR and undiversified VaR within each model.*

Table 4-22 shows there is an across the board noticeable reduction in risk when correlation is applied to each industry for both the Equity and Structural Models. There is also a shift in rankings. For example, with both models, Telecommunication Services shows very little reduction in risk through diversification and thus has a higher risk ranking on a diversified basis than undiversified. Other industries have risk reduction through diversification which approximates the overall portfolio average reduction, and thus retain a similar ranking on a diversified basis (for example Insurance, Paper & Forest Products, Utilities and Technology Hardware and Equipment).

Table 4-22 *Undiversified VaR compared to Diversified VaR – Equity & Structural Models*

The table compares undiversified (weighted average) VaR to diversified (correlated) VaR. Rankings are shown in the columns next to the VaR values, with a ranking of 1 being the highest risk and 25 the lowest. The final column under each model shows the squared ranking difference between undiversified and diversified VaR. This is an indicator of the strength of differences between undiversified and diversified rankings, and is an input into our significance calculation using a Spearman Rank Correlation Test.

| | **Equity model** | | | | | **Structural model** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Values** | | **Ranking** | | **Difference in Ranks$^2$** | **Values** | | **Ranking** | | **Difference in Ranks$^2$** |
| **Industry** | **Undiversified VaR** | **Diversified VaR** | **Undiversified VaR** | **Diversified VaR** | **Difference in Ranks$^2$** | **Undiversified PD** | **Diversified PD** | **Undiversified PD** | **Diversified PD** | **Difference in Ranks$^2$** |
| Automobiles & Components | 0.5417 | 0.3010 | 7 | 12 | 25 | 0.0163 | 0.0012 | 5 | 4 | 1 |
| Banks | 0.3030 | 0.2231 | 25 | 21 | 16 | 0.0044 | 0.0007 | 9 | 7 | 4 |
| Capital Goods | 0.4591 | 0.2369 | 15 | 18 | 9 | 0.0039 | 0.0000 | 11 | 17 | 36 |
| Chemicals | 0.4215 | 0.3106 | 18 | 11 | 49 | 0.0031 | 0.0004 | 13 | 8 | 25 |
| Commercial Services & Supplies | 0.5380 | 0.2424 | 8 | 17 | 81 | 0.0057 | 0.0000 | 8 | 18 | 100 |
| Construction Materials | 0.4424 | 0.3196 | 17 | 9 | 64 | 0.0009 | 0.0000 | 22 | 13 | 81 |
| Consumer Durables & Apparel | 0.5294 | 0.3901 | 10 | 3 | 49 | 0.0024 | 0.0003 | 15 | 9 | 36 |
| Diversified Financials | 0.4145 | 0.2008 | 19 | 24 | 25 | 0.0005 | 0.0000 | 24 | 23 | 1 |
| Energy | 0.5904 | 0.2858 | 5 | 13 | 64 | 0.0021 | 0.0000 | 19 | 21 | 4 |
| Food & Staples Retailing | 0.3727 | 0.2459 | 23 | 15 | 64 | 0.0015 | 0.0000 | 21 | 14 | 49 |
| Food Beverage & Tobacco | 0.3987 | 0.2022 | 20 | 23 | 9 | 0.0022 | 0.0000 | 18 | 19 | 1 |
| Healthcare Equipment & Services | 0.5246 | 0.2273 | 11 | 20 | 81 | 0.0031 | 0.0000 | 14 | 22 | 64 |
| Hotels Restaurants & Leisure | 0.5147 | 0.3148 | 12 | 10 | 4 | 0.0024 | 0.0000 | 16 | 15 | 1 |
| Insurance | 0.5366 | 0.3376 | 9 | 8 | 1 | 0.0422 | 0.0159 | 1 | 1 | 0 |
| Media | 0.4561 | 0.2317 | 16 | 19 | 9 | 0.0016 | 0.0000 | 20 | 20 | 0 |
| Metals & Mining | 0.5595 | 0.3382 | 6 | 7 | 1 | 0.0038 | 0.0001 | 12 | 12 | 0 |
| Paper & Forest Products | 0.6713 | 0.3612 | 4 | 5 | 1 | 0.0172 | 0.0011 | 4 | 5 | 1 |
| Pharmaceuticals & Biotechnology | 0.6729 | 0.3721 | 3 | 4 | 1 | 0.0062 | 0.0001 | 7 | 11 | 16 |
| Real Estate | 0.3931 | 0.1850 | 21 | 25 | 16 | 0.0005 | 0.0000 | 23 | 24 | 1 |
| Retailing | 0.5077 | 0.2821 | 13 | 14 | 1 | 0.0083 | 0.0002 | 6 | 10 | 16 |
| Software & Services | 0.8412 | 0.4353 | 2 | 2 | 0 | 0.0176 | 0.0008 | 3 | 6 | 9 |
| Technology Hardware & Equipment | 0.9514 | 0.4857 | 1 | 1 | 0 | 0.0295 | 0.0029 | 2 | 2 | 0 |
| Telecommunication Services | 0.3640 | 0.3455 | 24 | 6 | 324 | 0.0022 | 0.0015 | 17 | 3 | 196 |
| Transportation | 0.4732 | 0.2438 | 14 | 16 | 4 | 0.0043 | 0.0000 | 10 | 16 | 36 |
| Utilities | 0.3777 | 0.2035 | 22 | 22 | 0 | 0.0001 | 0.0000 | 25 | 25 | 0 |
| | | | | | 898 | | | | | 678 |
| | | | | *n* | 25 | | | | *n* | 25 |
| | | | | *r* | 0.655 | | | | *r* | 0.739 |
| | | | | *t* | 4.153 | | | | *t* | 5.264 |
| | | | | ***critical value 95%*** | 2.069 | | | | ***critical value 95%*** | 2.069 |
| | | | | ***critical value 99%*** | 2.807 | | | | ***critical value 99%*** | 2.807 |
| | | | | ***significance*** | ** | | | | ***significance*** | ** |

* denotes significance at the 95% confidence level

** denotes significance at the 99% confidence level

Our hypothesis testing finds significant association. The same applies to the Transition model as shown in Table 4-23 where there is also a noticeable reduction in VaR through diversification, and less of a noticeable change in rankings. For all 3 models, we reject the null hypothesis of no association between diversified and undiversified VaR.

Table 4-23 *Undiversified VaR Compared to Diversified VaR – Transition Model*

The table uses the same approach for the Transition model as outlined for the Structural and Equity models in Table 4-22.

| | | | Rank | | |
|---|---|---|---|---|---|
| **Industry** | **Undiversified VaR** | **Diversified VaR** | **Undiversified VaR** | **Diversified VaR** | **Difference in Ranks$^2$** |
| Banks | 0.0145 | 0.0128 | 14 | 14 | 0 |
| Diversified Financials | 0.0289 | 0.0135 | 10 | 13 | 9 |
| Energy | 0.0506 | 0.0453 | 7 | 5 | 4 |
| Food Beverage & Tobacco | 0.0743 | 0.0488 | 2 | 4 | 4 |
| Healthcare | 0.0929 | 0.0921 | 1 | 1 | 0 |
| Insurance | 0.0207 | 0.0150 | 12 | 12 | 0 |
| Media | 0.0533 | 0.0426 | 5 | 6 | 1 |
| Metals & Mining | 0.0209 | 0.0177 | 11 | 10 | 1 |
| Other Consumer Discretionary | 0.0739 | 0.0499 | 3 | 3 | 0 |
| Other Materials | 0.0592 | 0.0592 | 4 | 2 | 4 |
| Real Estate | 0.0328 | 0.0223 | 9 | 9 | 0 |
| Telecommunication Services | 0.0206 | 0.0154 | 13 | 11 | 4 |
| Transportation | 0.0512 | 0.0419 | 6 | 7 | 1 |
| Utilities | 0.0354 | 0.0274 | 8 | 8 | 0 |
| | | | | | 28 |
| | | | | ***n*** | 14 |
| | | | | ***r*** | 0.938 |
| | | | | ***t*** | 9.413 |
| | | | | ***critical value 95%*** | 2.179 |
| | | | | ***critical value 99%*** | 3.055 |
| | | | | ***significance*** | ** |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

### 4.4.4. $H_4$: There is association between VaR industry rankings and CVaR industry rankings within each of the models.

Table 4-24 *VaR Compared to CVaR – Equity & Structural Models*

Comparing VaR to parametric CVaR will not provide any benefit, as CVaR industry rankings are exactly the same as VaR, due to CVaR being the tail of the normal distribution. We have therefore used nonparametric CVaR (average of actual returns beyond VaR) to highlight the actual extreme risk.

| | Equity model | | | | | Structural model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Values | | Rank | | | Values | | Rank | | |
| **Industry** | **Undiversified Daily VaR** | **Nonparametric CVaR** | **Undiversified Daily VaR** | **Nonparametric CVaR** | **Difference in Ranks²** | **Undiversified PD** | **Nonparametric CPD** | **Undiversified PD** | **CPD** | **Difference in Ranks²** |
| Automobiles & Components | 0.0343 | 0.0536 | 7 | 7 | 0 | 0.0163 | 0.1104 | 5 | 3 | 4 |
| Banks | 0.0192 | 0.0268 | 25 | 25 | 0 | 0.0044 | 0.0750 | 9 | 15 | 36 |
| Capital Goods | 0.0290 | 0.0428 | 15 | 15 | 0 | 0.0039 | 0.0810 | 11 | 9 | 4 |
| Chemicals | 0.0267 | 0.0396 | 18 | 17 | 1 | 0.0031 | 0.0774 | 13 | 12 | 1 |
| Commercial Services & Supplies | 0.0340 | 0.0530 | 8 | 8 | 0 | 0.0057 | 0.0859 | 8 | 8 | 0 |
| Construction Materials | 0.0280 | 0.0390 | 17 | 19 | 4 | 0.0009 | 0.0586 | 22 | 23 | 1 |
| Consumer Durables & Apparel | 0.0335 | 0.0506 | 10 | 10 | 0 | 0.0024 | 0.0766 | 15 | 13 | 4 |
| Diversified Financials | 0.0262 | 0.0392 | 19 | 18 | 1 | 0.0005 | 0.0612 | 24 | 22 | 4 |
| Energy | 0.0373 | 0.0538 | 5 | 6 | 1 | 0.0021 | 0.0676 | 19 | 19 | 0 |
| Food & Staples Retailing | 0.0236 | 0.0343 | 23 | 24 | 1 | 0.0015 | 0.0644 | 21 | 21 | 0 |
| Food Beverage & Tobacco | 0.0252 | 0.0369 | 20 | 21 | 1 | 0.0022 | 0.0699 | 18 | 17 | 1 |
| Healthcare Equipment & Services | 0.0332 | 0.0499 | 11 | 11 | 0 | 0.0031 | 0.0798 | 14 | 10 | 16 |
| Hotels Restaurants & Leisure | 0.0326 | 0.0510 | 12 | 9 | 9 | 0.0024 | 0.0737 | 16 | 16 | 0 |
| Insurance | 0.0339 | 0.0586 | 9 | 5 | 16 | 0.0422 | 0.1206 | 1 | 1 | 0 |
| Media | 0.0288 | 0.0417 | 16 | 16 | 0 | 0.0016 | 0.0673 | 20 | 20 | 0 |
| Metals & Mining | 0.0354 | 0.0498 | 6 | 12 | 36 | 0.0038 | 0.0697 | 12 | 18 | 36 |
| Paper & Forest Products | 0.0425 | 0.0653 | 4 | 4 | 0 | 0.0172 | 0.1042 | 4 | 5 | 1 |
| Pharmaceuticals & Biotechnology | 0.0426 | 0.0656 | 3 | 3 | 0 | 0.0062 | 0.0903 | 7 | 6 | 1 |
| Real Estate | 0.0249 | 0.0381 | 21 | 20 | 1 | 0.0005 | 0.0576 | 23 | 24 | 1 |
| Retailing | 0.0321 | 0.0469 | 13 | 13 | 0 | 0.0083 | 0.0895 | 6 | 7 | 1 |
| Software & Services | 0.0532 | 0.0862 | 2 | 2 | 0 | 0.0176 | 0.1068 | 3 | 4 | 1 |
| Technology Hardware & Equipment | 0.0602 | 0.0964 | 1 | 1 | 0 | 0.0295 | 0.1167 | 2 | 2 | 0 |
| Telecommunication Services | 0.0230 | 0.0343 | 24 | 23 | 1 | 0.0022 | 0.0755 | 17 | 14 | 9 |
| Transportation | 0.0299 | 0.0451 | 14 | 14 | 0 | 0.0043 | 0.0794 | 10 | 11 | 1 |
| Utilities | 0.0239 | 0.0351 | 22 | 22 | 0 | 0.0001 | 0.0453 | 25 | 25 | 0 |
| | | | | | 72 | | | | | 122 |
| | | | | ***n*** | 25 | | | | ***n*** | 25 |
| | | | | ***r*** | 0.972 | | | | ***r*** | 0.953 |
| | | | | ***t*** | 19.953 | | | | ***t*** | 15.099 |
| | | | | ***critical value 95%*** | 2.069 | | | | ***critical value 95%*** | 2.069 |
| | | | | ***critical value 99%*** | 2.807 | | | | ***critical value 99%*** | 2.807 |
| | | | | ***significance*** | ** | | | | ***significance*** | ** |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

Both models display some differences in VaR and CVaR rankings which would not be apparent with a parametric approach. For example, Insurance moves from risk ranking 9 to a higher risk ranking of 5 on the Equity model, and Banks from 9 to 15 on the Structural model. But in the main, most industries have similar VaR and CVaR rankings. A very similar pattern is evident for the Transition model shown in Table 4-25. Our hypothesis testing finds significant association, so we reject the null hypothesis of no association between VaR and CVaR rankings for all 3 models.

Table 4-25 *VaR Compared to CVaR - Transition Model*

The Transition model comparison follows the same approach for the VaR and CVaR comparisons of the Equity and Structural models in Table 4-24. We use the nonparametric Analytic CVaR method for comparison to VaR. A comparison between the industry rankings of different CVaR methods is provided in Table 4-31 and Table 4-32.

| | | | Rank | | |
|---|---|---|---|---|---|
| **Industry** | **Undiversified VaR** | **Analytical CVaR** | **Undiversified VaR** | **Analytical CVaR** | **Difference in Ranks$^2$** |
| Banks | 0.0145 | 0.0131 | 14 | 14 | 0 |
| Diversified Financials | 0.0289 | 0.0669 | 10 | 7 | 9 |
| Energy | 0.0506 | 0.0579 | 7 | 8 | 1 |
| Food Beverage & Tobacco | 0.0743 | 0.1787 | 2 | 1 | 1 |
| Healthcare | 0.0929 | 0.1588 | 1 | 2 | 1 |
| Insurance | 0.0207 | 0.0237 | 12 | 11 | 1 |
| Media | 0.0533 | 0.0674 | 5 | 6 | 1 |
| Metals & Mining | 0.0209 | 0.0212 | 11 | 13 | 4 |
| Other Consumer Discretionary | 0.0739 | 0.1417 | 3 | 3 | 0 |
| Other Materials | 0.0592 | 0.0685 | 4 | 5 | 1 |
| Real Estate | 0.0328 | 0.0470 | 9 | 9 | 0 |
| Telecommunication Services | 0.0206 | 0.0225 | 13 | 12 | 1 |
| Transportation | 0.0512 | 0.0785 | 6 | 4 | 4 |
| Utilities | 0.0354 | 0.0456 | 8 | 10 | 4 |
| | | | | | 28 |
| | | | | ***n*** | 14 |
| | | | | ***r*** | 0.938 |
| | | | | ***t*** | 9.413 |
| | | | | ***critical value 95%*** | 2.179 |
| | | | | ***critical value 99%*** | 3.055 |
| | | | | ***significance*** | ** |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

### 4.4.5. *$H_5$: There is association in CVaR industry rankings between the Structural and Equity models.*

Table 4-26 *CVaR Comparison Between Equity and Structural Models*

The table makes a comparison between the models for parametric CVaR on the left of the table and for nonparametric CVaR on the right side of the table. The test applied is a Spearman Rank Correlation Test.

| | **Parametric CVaR:** | | | | | **Nonparametric CVaR:** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Values** | | **Ranking** | | **Difference in Ranks$^2$** | **Values** | | **Ranking** | | **Difference in Ranks$^2$** |
| **Industry** | **Equity Model CVaR** | **Structural Model CPD** | **Equity Model CVaR** | **Structural Model CPD** | **Equity / Structural** | **Equity Model CVaR** | **Structural Model CPD** | **Equity Model CVaR** | **Structural Model CPD** | **Equity / Structural** |
| Automobiles & Components | 0.0430 | 0.0604 | 7 | 5 | 4 | 0.0536 | 0.1104 | 7 | 3 | 16 |
| Banks | 0.0240 | 0.0371 | 25 | 9 | 256 | 0.0268 | 0.0750 | 25 | 15 | 100 |
| Capital Goods | 0.0364 | 0.0354 | 15 | 11 | 16 | 0.0428 | 0.0810 | 15 | 9 | 36 |
| Chemicals | 0.0334 | 0.0327 | 18 | 13 | 25 | 0.0396 | 0.0774 | 17 | 12 | 25 |
| Commercial Services & Supplies | 0.0427 | 0.0408 | 8 | 8 | 0 | 0.0530 | 0.0859 | 8 | 8 | 0 |
| Construction Materials | 0.0351 | 0.0214 | 17 | 22 | 25 | 0.0390 | 0.0586 | 19 | 23 | 16 |
| Consumer Durables & Apparel | 0.0420 | 0.0299 | 10 | 15 | 25 | 0.0506 | 0.0766 | 10 | 13 | 9 |
| Diversified Financials | 0.0329 | 0.0175 | 19 | 24 | 25 | 0.0392 | 0.0612 | 18 | 22 | 16 |
| Energy | 0.0468 | 0.0284 | 5 | 19 | 196 | 0.0538 | 0.0676 | 6 | 19 | 169 |
| Food & Staples Retailing | 0.0295 | 0.0252 | 23 | 21 | 4 | 0.0343 | 0.0644 | 24 | 21 | 9 |
| Food Beverage & Tobacco | 0.0316 | 0.0289 | 20 | 18 | 4 | 0.0369 | 0.0699 | 21 | 17 | 16 |
| Healthcare Equipment & Services | 0.0416 | 0.0327 | 11 | 14 | 9 | 0.0499 | 0.0798 | 11 | 10 | 1 |
| Hotels Restaurants & Leisure | 0.0408 | 0.0298 | 12 | 16 | 16 | 0.0510 | 0.0737 | 9 | 16 | 49 |
| Insurance | 0.0425 | 0.0883 | 9 | 1 | 64 | 0.0586 | 0.1206 | 5 | 1 | 16 |
| Media | 0.0362 | 0.0257 | 16 | 20 | 16 | 0.0417 | 0.0673 | 16 | 20 | 16 |
| Metals & Mining | 0.0444 | 0.0353 | 6 | 12 | 36 | 0.0498 | 0.0697 | 12 | 18 | 36 |
| Paper & Forest Products | 0.0532 | 0.0617 | 4 | 4 | 0 | 0.0653 | 0.1042 | 4 | 5 | 1 |
| Pharmaceuticals & Biotechnology | 0.0534 | 0.0422 | 3 | 7 | 16 | 0.0656 | 0.0903 | 3 | 6 | 9 |
| Real Estate | 0.0312 | 0.0180 | 21 | 23 | 4 | 0.0381 | 0.0576 | 20 | 24 | 16 |
| Retailing | 0.0403 | 0.0468 | 13 | 6 | 49 | 0.0469 | 0.0895 | 13 | 7 | 36 |
| Software & Services | 0.0667 | 0.0623 | 2 | 3 | 1 | 0.0862 | 0.1068 | 2 | 4 | 4 |
| Technology Hardware & Equipment | 0.0754 | 0.0763 | 1 | 2 | 1 | 0.0964 | 0.1167 | 1 | 2 | 1 |
| Telecommunication Services | 0.0289 | 0.0291 | 24 | 17 | 49 | 0.0343 | 0.0755 | 23 | 14 | 81 |
| Transportation | 0.0375 | 0.0367 | 14 | 10 | 16 | 0.0451 | 0.0794 | 14 | 11 | 9 |
| Utilities | 0.0299 | 0.0101 | 22 | 25 | 9 | 0.0351 | 0.0453 | 22 | 25 | 9 |
| | | | | | 866 | | | | | 696 |
| | | | | *n* | 25 | | | | *n* | 25 |
| | | | | *r* | 0.667 | | | | *r* | 0.732 |
| | | | | *t* | 4.292 | | | | *t* | 5.157 |
| | | | | *critical value 95%* | 2.069 | | | | *critical value 95%* | 2.069 |
| | | | | *critical value 99%* | 2.807 | | | | *critical value 99%* | 2.807 |
| | | | | *significance* | ** | | | | *significance* | ** |

* denotes significance at the 95% confidence level

** denotes significance at the 99% confidence level

The parametric CVaR rankings for the Equity and Structural models are the same as the VaR rankings that we have already commented on under Hypothesis 1. The CVaR numbers are just larger, being the tail end of the distribution. The nonparametric rankings show some industries with similar rankings between the models, such as Commercial Services & Supplies, Healthcare Equipment & Services, Paper & Forest Products, and Technology Hardware & Equipment. Large differences occur in the CVaR of Banking, Energy, and Telecommunication Services. The Technology sectors show very high CVaR on both models. The similarities are sufficient for the hypothesis testing to show association, and we thus reject the null hypothesis of no association in CVaR rankings between the Structural and Equity models.

#### 4.4.6. *$H_6$: Industry CVaR does not stay constant over time.*

Table 4-27 *Equity Model Historical Daily Nonparametric CVaR*

The table shows undiversified industry CVaR for each of the nine 7 year rolling window periods. This is the weighted average of the actual daily returns beyond VaR. Year 1 contains data for years 1-7. Year 2 contains data for years 2-8 and so on through to year nine which contains data for years 9-15.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 0.0536 | 0.0525 | 0.0503 | 0.0495 | 0.0499 | 0.0450 | 0.0449 | 0.0428 | 0.0418 |
| Banks | 0.0268 | 0.0280 | 0.0293 | 0.0312 | 0.0316 | 0.0309 | 0.0306 | 0.0302 | 0.0299 |
| Capital Goods | 0.0428 | 0.0432 | 0.0450 | 0.0462 | 0.0445 | 0.0439 | 0.0533 | 0.0467 | 0.0472 |
| Chemicals | 0.0396 | 0.0402 | 0.0382 | 0.0413 | 0.0440 | 0.0441 | 0.0420 | 0.0435 | 0.0456 |
| Commercial Services & Supplies | 0.0530 | 0.0516 | 0.0568 | 0.0586 | 0.0532 | 0.0489 | 0.0468 | 0.0408 | 0.0400 |
| Construction Materials | 0.0390 | 0.0377 | 0.0400 | 0.0406 | 0.0466 | 0.0447 | 0.0449 | 0.0458 | 0.0442 |
| Consumer Durables & Apparel | 0.0506 | 0.0542 | 0.0593 | 0.0663 | 0.0593 | 0.0618 | 0.0422 | 0.0707 | 0.0648 |
| Diversified Financials | 0.0392 | 0.0407 | 0.0433 | 0.0467 | 0.0501 | 0.0496 | 0.0569 | 0.0560 | 0.0489 |
| Energy | 0.0538 | 0.0539 | 0.0543 | 0.0518 | 0.0519 | 0.0516 | 0.0488 | 0.0501 | 0.0468 |
| Food & Staples Retailing | 0.0343 | 0.0360 | 0.0381 | 0.0398 | 0.0396 | 0.0381 | 0.0327 | 0.0321 | 0.0311 |
| Food Beverage & Tobacco | 0.0369 | 0.0433 | 0.0500 | 0.0605 | 0.0556 | 0.0509 | 0.0551 | 0.0497 | 0.0466 |
| Healthcare Equipment & Services | 0.0499 | 0.0540 | 0.0576 | 0.0604 | 0.0580 | 0.0577 | 0.0563 | 0.0540 | 0.0470 |
| Hotels Restaurants & Leisure | 0.0510 | 0.0463 | 0.0471 | 0.0439 | 0.0438 | 0.0465 | 0.0483 | 0.0504 | 0.0363 |
| Insurance | 0.0586 | 0.0577 | 0.0592 | 0.0594 | 0.0490 | 0.0405 | 0.0422 | 0.0389 | 0.0505 |
| Media | 0.0417 | 0.0430 | 0.0451 | 0.0450 | 0.0431 | 0.0435 | 0.0509 | 0.0444 | 0.0431 |
| Metals & Mining | 0.0498 | 0.0500 | 0.0521 | 0.0519 | 0.0507 | 0.0481 | 0.0540 | 0.0496 | 0.0500 |
| Paper & Forest Products | 0.0653 | 0.0648 | 0.0606 | 0.0545 | 0.0497 | 0.0514 | 0.0489 | 0.0803 | 0.0538 |
| Pharmaceuticals & Biotechnology | 0.0656 | 0.0747 | 0.0817 | 0.0952 | 0.0787 | 0.0614 | 0.0692 | 0.0636 | 0.0543 |
| Real Estate | 0.0381 | 0.0395 | 0.0416 | 0.0406 | 0.0393 | 0.0380 | 0.0403 | 0.0373 | 0.0366 |
| Retailing | 0.0469 | 0.0470 | 0.0425 | 0.0510 | 0.0502 | 0.0480 | 0.0455 | 0.0434 | 0.0430 |
| Software & Services | 0.0862 | 0.0926 | 0.0978 | 0.1067 | 0.0928 | 0.0842 | 0.1761 | 0.1837 | 0.0889 |
| Technology Hardware & Equipment | 0.0964 | 0.0859 | 0.0908 | 0.0987 | 0.0987 | 0.0943 | 0.0865 | 0.0809 | 0.0738 |
| Telecommunication Services | 0.0343 | 0.0353 | 0.0414 | 0.0449 | 0.0474 | 0.0523 | 0.0772 | 0.0729 | 0.1830 |
| Transportation | 0.0451 | 0.0458 | 0.0450 | 0.0479 | 0.0514 | 0.0471 | 0.0423 | 0.0386 | 0.0381 |
| Utilities | 0.0351 | 0.0358 | 0.0357 | 0.0396 | 0.0392 | 0.0413 | 0.0427 | 0.0438 | 0.0399 |
| Portfolio | 0.0421 | 0.0430 | 0.0450 | 0.0464 | 0.0453 | 0.0435 | 0.0469 | 0.0449 | 0.0480 |

The overall portfolio shows a fairly narrow range from 4.21% to 4.8%. Some of the individual industries however, show more volatility. For example, Consumer Durables and Apparel ranges from 4.22% to 7.07%, indicating some extreme events in year 8. The same applies to Pharmaceuticals & Biotechnology with a range from 5.43% to 9.52%, with the extreme events occurring in year 4. Software & Services shows a spike to 17.61% in year 7 and 18.37% in year 8. We note that in these industries, the worst years for CVaR correspond with the worst years for VaR. Table 4-28 shows that there are no significant differences in CVaR over time for the Equity model.

Table 4-28 *Significance Testing – Equity Model Historical Undiversified CVaR*

The table shows rankings for the undiversified CVaR values in Table 4-27. A ranking of 1 (Software & Services in year 8) is the highest risk, and 225 (Banks in year 1) the lowest risk. A Kruskal-Wallis test, as described in Section 3.8.2.2, is applied.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 66 | 70 | 88 | 102 | 96 | 135 | 138 | 161 | 169 |
| Banks | 225 | 224 | 223 | 217 | 216 | 219 | 220 | 221 | 222 |
| Capital Goods | 162 | 156 | 136 | 127 | 142 | 147 | 67 | 122 | 113 |
| Chemicals | 186 | 181 | 196 | 173 | 146 | 145 | 168 | 152 | 130 |
| Commercial Services & Supplies | 69 | 76 | 51 | 44 | 68 | 105 | 119 | 175 | 183 |
| Construction Materials | 193 | 202 | 182 | 177 | 123 | 141 | 140 | 129 | 144 |
| Consumer Durables & Apparel | 85 | 59 | 42 | 29 | 41 | 35 | 167 | 27 | 32 |
| Diversified Financials | 192 | 176 | 154 | 121 | 91 | 100 | 50 | 53 | 104 |
| Energy | 64 | 63 | 58 | 75 | 74 | 77 | 107 | 90 | 120 |
| Food & Staples Retailing | 213 | 207 | 200 | 185 | 187 | 197 | 214 | 215 | 218 |
| Food Beverage & Tobacco | 204 | 155 | 93 | 38 | 54 | 82 | 55 | 98 | 124 |
| Healthcare Equipment & Services | 95 | 61 | 49 | 39 | 46 | 48 | 52 | 60 | 117 |
| Hotels Restaurants & Leisure | 80 | 126 | 114 | 148 | 149 | 125 | 108 | 87 | 206 |
| Insurance | 45 | 47 | 43 | 40 | 103 | 179 | 166 | 194 | 86 |
| Media | 170 | 160 | 133 | 137 | 157 | 151 | 83 | 143 | 158 |
| Metals & Mining | 97 | 94 | 72 | 73 | 84 | 109 | 62 | 101 | 92 |
| Paper & Forest Products | 31 | 33 | 37 | 56 | 99 | 79 | 106 | 21 | 65 |
| Pharmaceuticals & Biotechnology | 30 | 24 | 19 | 9 | 22 | 36 | 28 | 34 | 57 |
| Real Estate | 198 | 189 | 171 | 178 | 190 | 201 | 180 | 203 | 205 |
| Retailing | 118 | 116 | 164 | 81 | 89 | 110 | 131 | 153 | 159 |
| Software & Services | 16 | 12 | 7 | 4 | 11 | 18 | 3 | 1 | 14 |
| Technology Hardware & Equipment | 8 | 17 | 13 | 6 | 5 | 10 | 15 | 20 | 25 |
| Telecommunication Services | 212 | 210 | 172 | 139 | 112 | 71 | 23 | 26 | 2 |
| Transportation | 132 | 128 | 134 | 111 | 78 | 115 | 165 | 195 | 199 |
| Utilities | 211 | 208 | 209 | 188 | 191 | 174 | 163 | 150 | 184 |
| ***R*** | 3102 | 2994 | 2760 | 2497 | 2574 | 2809 | 2730 | 2831 | 3128 |
| ***n*** | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| $\sum n$ | 225 | | | | | | | | |
| ***degrees of freedom*** | 8 | | | | | | | | |
| ***K*** | 3.60 | | | | | | | | |
| ***critical value 95%*** | 15.51 | | | ***critical value 99%*** | | | 20.09 | | |
| ***significance*** | - | | | | | | | | |

* denotes significance at the 95% confidence level

** denotes significance at the 99% confidence level

For the Structural model shown in Table 4-29 we also note a fairly narrow portfolio CPD range from 7.56% to 8.27%. Again, some individual industries show varying volatility. Due to balance sheet influences on the Structural model, these variances are not necessarily the same as for the Equity model. For example, Software and Services show a fairly constant CPD over time for the Structural model, as compared to the spikes shown by the Equity model. For Construction Materials, which shows a narrow range for the Equity models, the Structural model shows a much broader range from 5.17% to 8.89%.

Table 4-29 *Structural Model Historical CPD*

The table shows undiversified nonparametric industry CPD for each of the nine 7 year rolling window periods. This is the weighted average of the actual worst 5% of returns. Year 1 contains data for years 1-7. Year 2 contains data for years 2-8 and so on through to year nine which contains data for years 9-15.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 0.1104 | 0.1106 | 0.1055 | 0.1029 | 0.1019 | 0.0998 | 0.1012 | 0.0941 | 0.0949 |
| Banks | 0.0750 | 0.0783 | 0.0820 | 0.0827 | 0.0820 | 0.0812 | 0.0814 | 0.0786 | 0.0786 |
| Capital Goods | 0.0810 | 0.0810 | 0.0852 | 0.0861 | 0.0846 | 0.0825 | 0.0872 | 0.0916 | 0.0974 |
| Chemicals | 0.0774 | 0.0807 | 0.0784 | 0.0758 | 0.0891 | 0.0914 | 0.0899 | 0.0791 | 0.0802 |
| Commercial Services & Supplies | 0.0859 | 0.0790 | 0.0925 | 0.0955 | 0.0878 | 0.0797 | 0.0741 | 0.0658 | 0.0683 |
| Construction Materials | 0.0586 | 0.0517 | 0.0589 | 0.0617 | 0.0779 | 0.0774 | 0.0889 | 0.0811 | 0.0810 |
| Consumer Durables & Apparel | 0.0766 | 0.0803 | 0.0898 | 0.0979 | 0.0942 | 0.0836 | 0.0474 | 0.1208 | 0.1174 |
| Diversified Financials | 0.0612 | 0.0604 | 0.0629 | 0.0711 | 0.0726 | 0.0627 | 0.0637 | 0.0686 | 0.0722 |
| Energy | 0.0676 | 0.0676 | 0.0714 | 0.0715 | 0.0692 | 0.0666 | 0.0651 | 0.0641 | 0.0652 |
| Food & Staples Retailing | 0.0644 | 0.0677 | 0.0751 | 0.0771 | 0.0770 | 0.0719 | 0.0665 | 0.0645 | 0.0635 |
| Food Beverage & Tobacco | 0.0699 | 0.0750 | 0.0832 | 0.0845 | 0.0831 | 0.0807 | 0.0836 | 0.0835 | 0.0907 |
| Healthcare Equipment & Services | 0.0798 | 0.0860 | 0.0910 | 0.0967 | 0.0973 | 0.0942 | 0.0957 | 0.0944 | 0.0957 |
| Hotels Restaurants & Leisure | 0.0737 | 0.0786 | 0.0733 | 0.0735 | 0.0732 | 0.0753 | 0.0755 | 0.0757 | 0.0587 |
| Insurance | 0.1206 | 0.1218 | 0.1219 | 0.1220 | 0.1169 | 0.1135 | 0.1189 | 0.1221 | 0.1341 |
| Media | 0.0673 | 0.0680 | 0.0724 | 0.0753 | 0.0773 | 0.0783 | 0.0842 | 0.0783 | 0.0755 |
| Metals & Mining | 0.0697 | 0.0697 | 0.0734 | 0.0762 | 0.0785 | 0.0739 | 0.0744 | 0.0676 | 0.0651 |
| Paper & Forest Products | 0.1042 | 0.1054 | 0.0953 | 0.0881 | 0.0863 | 0.0854 | 0.0799 | 0.1074 | 0.1040 |
| Pharmaceuticals & Biotechnology | 0.0903 | 0.0951 | 0.0996 | 0.1052 | 0.0994 | 0.0850 | 0.0844 | 0.0819 | 0.0784 |
| Real Estate | 0.0576 | 0.0608 | 0.0611 | 0.0644 | 0.0661 | 0.0666 | 0.0675 | 0.0670 | 0.0703 |
| Retailing | 0.0895 | 0.0889 | 0.0672 | 0.0957 | 0.0954 | 0.0932 | 0.0901 | 0.0867 | 0.0892 |
| Software & Services | 0.1068 | 0.1089 | 0.1118 | 0.1167 | 0.1080 | 0.0970 | 0.1127 | 0.1118 | 0.0984 |
| Technology Hardware & Equipment | 0.1167 | 0.1184 | 0.1236 | 0.1349 | 0.1375 | 0.1336 | 0.1268 | 0.1220 | 0.1237 |
| Telecommunication Services | 0.0755 | 0.0698 | 0.0779 | 0.0811 | 0.0823 | 0.0858 | 0.0854 | 0.0544 | 0.0862 |
| Transportation | 0.0794 | 0.0793 | 0.0799 | 0.0842 | 0.0884 | 0.0862 | 0.0790 | 0.0712 | 0.0719 |
| Utilities | 0.0453 | 0.0447 | 0.0590 | 0.0594 | 0.0571 | 0.0649 | 0.0641 | 0.0656 | 0.0630 |
| Portfolio | 0.0756 | 0.0775 | 0.0809 | 0.0827 | 0.0825 | 0.0805 | 0.0810 | 0.0783 | 0.0800 |

Hypothesis testing in Table 4-30 finds no significant CPD differences over time for the Structural model.

Table 4-30 *Significance Testing - Structural Model Historical CPD*

The table shows rankings for the undiversified CVaR values in Table 4-29. A ranking of 1 (Technology Hardware & Equipment in year 5) is the highest risk, and 225 (Utilities in year 2) the lowest risk. A Kruskal-Wallis test, as described in Section 3.8.2.2., is applied.

| Industry | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|---|---|---|---|
| Automobiles & Components | 26 | 25 | 31 | 36 | 37 | 39 | 38 | 59 | 55 |
| Banks | 154 | 133 | 105 | 101 | 104 | 108 | 107 | 128 | 129 |
| Capital Goods | 112 | 111 | 89 | 83 | 91 | 102 | 78 | 62 | 44 |
| Chemicals | 138 | 114 | 131 | 145 | 72 | 63 | 68 | 124 | 117 |
| Commercial Services & Supplies | 85 | 125 | 61 | 51 | 77 | 121 | 156 | 193 | 179 |
| Construction Materials | 218 | 222 | 216 | 209 | 137 | 139 | 73 | 110 | 113 |
| Consumer Durables & Apparel | 143 | 116 | 69 | 43 | 57 | 96 | 223 | 13 | 17 |
| Diversified Financials | 210 | 213 | 207 | 171 | 163 | 208 | 204 | 178 | 165 |
| Energy | 182 | 184 | 169 | 168 | 177 | 189 | 196 | 203 | 195 |
| Food & Staples Retailing | 200 | 181 | 152 | 141 | 142 | 167 | 191 | 199 | 205 |
| Food Beverage & Tobacco | 173 | 153 | 99 | 92 | 100 | 115 | 97 | 98 | 65 |
| Healthcare Equipment & Services | 120 | 84 | 64 | 47 | 45 | 58 | 50 | 56 | 48 |
| Hotels Restaurants & Leisure | 158 | 127 | 161 | 159 | 162 | 150 | 149 | 146 | 217 |
| Insurance | 14 | 12 | 11 | 9 | 18 | 21 | 15 | 8 | 3 |
| Media | 186 | 180 | 164 | 151 | 140 | 134 | 94 | 135 | 147 |
| Metals & Mining | 175 | 176 | 160 | 144 | 130 | 157 | 155 | 183 | 197 |
| Paper & Forest Products | 34 | 32 | 53 | 76 | 80 | 87 | 118 | 29 | 35 |
| Pharmaceuticals & Biotechnology | 66 | 54 | 40 | 33 | 41 | 90 | 93 | 106 | 132 |
| Real Estate | 219 | 212 | 211 | 201 | 192 | 190 | 185 | 188 | 172 |
| Retailing | 70 | 74 | 187 | 49 | 52 | 60 | 67 | 79 | 71 |
| Software & Services | 30 | 27 | 24 | 20 | 28 | 46 | 22 | 23 | 42 |
| Technology Hardware & Equipment | 19 | 16 | 7 | 2 | 1 | 4 | 5 | 10 | 6 |
| Telecommunication Services | 148 | 174 | 136 | 109 | 103 | 86 | 88 | 221 | 82 |
| Transportation | 122 | 123 | 119 | 95 | 75 | 81 | 126 | 170 | 166 |
| Utilities | 224 | 225 | 215 | 214 | 220 | 198 | 202 | 194 | 206 |
| ***R*** | 3226 | 3093 | 2881 | 2549 | 2444 | 2709 | 2800 | 2915 | 2808 |
| ***n*** | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| $\sum n$ | 225 | | | | | | | | |
| ***degrees of freedom*** | 8 | | | | | | | | |
| ***K*** | 4.53 | | | | | | | | |
| ***critical value 95%*** | 15.51 | | | ***critical value 99%*** | | | 20.09 | | |
| ***significance*** | - | | | | | | | | |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

As CVaR differences over time are not found by our Hypothesis testing to be significant for either the Equity and Structural models, we accept the null hypothesis of association in CVaR rankings over time.

### 4.4.7. $H_7$: *There is association between parametric and nonparametric CVaR industry rankings within each of the models.*

Table 4-31 *Parametric Compared to Nonparametric CVaR: Equity & Structural Models*

The table compares the two types of CVaR (parametric and nonparametric) within each model. Parametric CVaR gives the same industry rankings as VaR as it is the 5% tail of the normal distribution. Large differences between parametric and nonparametric CVaR would show that the tail is not normally distributed. A Spearman Rank Correlation test is applied.

| | Equity Model | | | | | Structural Model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Values | | Ranking | | Difference in Ranks² | Values | | Ranking | | Difference in Ranks² |
| **Industry** | **Parametric CVaR** | **Nonparametric Cvar** | **Parametric CVaR** | **Nonparametric Cvar** | **Difference in Ranks²** | **Parametric CPD** | **Nonparametric CPD** | **Parametric CPD** | **Nonparametric CPD** | **Difference in Ranks²** |
| Automobiles & Components | 0.0430 | 0.0536 | 7 | 7 | 0 | 0.0604 | 0.1104 | 5 | 3 | 4 |
| Banks | 0.0240 | 0.0268 | 25 | 25 | 0 | 0.0371 | 0.0750 | 9 | 15 | 36 |
| Capital Goods | 0.0364 | 0.0428 | 15 | 15 | 0 | 0.0354 | 0.0810 | 11 | 9 | 4 |
| Chemicals | 0.0334 | 0.0396 | 18 | 17 | 1 | 0.0327 | 0.0774 | 13 | 12 | 1 |
| Commercial Services & Supplies | 0.0427 | 0.0530 | 8 | 8 | 0 | 0.0408 | 0.0859 | 8 | 8 | 0 |
| Construction Materials | 0.0351 | 0.0390 | 17 | 19 | 4 | 0.0214 | 0.0586 | 22 | 23 | 1 |
| Consumer Durables & Apparel | 0.0420 | 0.0506 | 10 | 10 | 0 | 0.0299 | 0.0766 | 15 | 13 | 4 |
| Diversified Financials | 0.0329 | 0.0392 | 19 | 18 | 1 | 0.0175 | 0.0612 | 24 | 22 | 4 |
| Energy | 0.0468 | 0.0538 | 5 | 6 | 1 | 0.0284 | 0.0676 | 19 | 19 | 0 |
| Food & Staples Retailing | 0.0295 | 0.0343 | 23 | 24 | 1 | 0.0252 | 0.0644 | 21 | 21 | 0 |
| Food Beverage & Tobacco | 0.0316 | 0.0369 | 20 | 21 | 1 | 0.0289 | 0.0699 | 18 | 17 | 1 |
| Healthcare Equipment & Services | 0.0416 | 0.0499 | 11 | 11 | 0 | 0.0327 | 0.0798 | 14 | 10 | 16 |
| Hotels Restaurants & Leisure | 0.0408 | 0.0510 | 12 | 9 | 9 | 0.0298 | 0.0737 | 16 | 16 | 0 |
| Insurance | 0.0425 | 0.0586 | 9 | 5 | 16 | 0.0883 | 0.1206 | 1 | 1 | 0 |
| Media | 0.0362 | 0.0417 | 16 | 16 | 0 | 0.0257 | 0.0673 | 20 | 20 | 0 |
| Metals & Mining | 0.0444 | 0.0498 | 6 | 12 | 36 | 0.0353 | 0.0697 | 12 | 18 | 36 |
| Paper & Forest Products | 0.0532 | 0.0653 | 4 | 4 | 0 | 0.0617 | 0.1042 | 4 | 5 | 1 |
| Pharmaceuticals & Biotechnology | 0.0534 | 0.0656 | 3 | 3 | 0 | 0.0422 | 0.0903 | 7 | 6 | 1 |
| Real Estate | 0.0312 | 0.0381 | 21 | 20 | 1 | 0.0180 | 0.0576 | 23 | 24 | 1 |
| Retailing | 0.0403 | 0.0469 | 13 | 13 | 0 | 0.0468 | 0.0895 | 6 | 7 | 1 |
| Software & Services | 0.0667 | 0.0862 | 2 | 2 | 0 | 0.0623 | 0.1068 | 3 | 4 | 1 |
| Technology Hardware & Equipment | 0.0754 | 0.0964 | 1 | 1 | 0 | 0.0763 | 0.1167 | 2 | 2 | 0 |
| Telecommunication Services | 0.0289 | 0.0343 | 24 | 23 | 1 | 0.0291 | 0.0755 | 17 | 14 | 9 |
| Transportation | 0.0375 | 0.0451 | 14 | 14 | 0 | 0.0367 | 0.0794 | 10 | 11 | 1 |
| Utilities | 0.0299 | 0.0351 | 22 | 22 | 0 | 0.0101 | 0.0453 | 25 | 25 | 0 |
| | | | | | 72 | | | | | 122 |
| | | | | *n* | 25 | | | | *n* | 25 |
| | | | | *r* | 0.972 | | | | *r* | 0.953 |
| | | | | *t* | 19.95 | | | | *t* | 15.1 |
| | | | | *critical value 95%* | 2.069 | | | | *critical value 95%* | 2.069 |
| | | | | *critical value 99%* | 2.807 | | | | *critical value 99%* | 2.807 |
| | | | | *significance* | ** | | | | *significance* | ** |

* denotes significance at the 95% confidence level

** denotes significance at the 99% confidence level

Parametric CVaR in Table 4-31 gives the same rankings as VaR in Table 4-24, due to being the 5% tail end of the normal distribution. In most industries there is little difference in rankings between parametric and nonparametric VaR, but there are more marked differences in some industries such as Metals & Mining, where clearly the extreme activity does not follow a standard distribution.

For the Transition model, we compare 3 approaches in Table 4-32. This includes the parametric approach, the nonparametric Analytical approach which we have developed during this study, and the Monte Carlo approach. These approaches are all discussed in Sections 2.7 and 3.5.3.

Table 4-32 *Parametric Compared to Nonparametric CVaR – Transition Model*

The same approach to hypothesis testing is used as for the Structural and Equity models in Table 4-31.

| | Values | | | Ranking | | | Difference in Ranks² | | |
|---|---|---|---|---|---|---|---|---|---|
| **Industry** | **CVaR Parametric** | **CVaR Analytical** | **CVaR Monte Carlo** | **CVaR Parametric** | **CVaR Analytical** | **CVaR Monte Carlo** | **Parametric / Analytical** | **Parametric / Monte Carlo** | **Analytical / Monte Carlo** |
| Banks | 0.0181 | 0.0131 | 0.0135 | 14 | 14 | 14 | 0 | 0 | 0 |
| Diversified Financials | 0.0362 | 0.0669 | 0.0658 | 10 | 7 | 7 | 9 | 9 | 0 |
| Energy | 0.0634 | 0.0579 | 0.0598 | 7 | 8 | 8 | 1 | 1 | 0 |
| Food Beverage & Tobacco | 0.0932 | 0.1787 | 0.1730 | 2 | 1 | 1 | 1 | 1 | 0 |
| Healthcare | 0.1164 | 0.1588 | 0.1629 | 1 | 2 | 2 | 1 | 1 | 0 |
| Insurance | 0.0259 | 0.0237 | 0.0232 | 12 | 11 | 11 | 1 | 1 | 0 |
| Media | 0.0668 | 0.0674 | 0.0722 | 5 | 6 | 5 | 1 | 0 | 1 |
| Metals & Mining | 0.0262 | 0.0212 | 0.0204 | 11 | 13 | 13 | 4 | 4 | 0 |
| Other Consumer Discretionary | 0.0926 | 0.1417 | 0.1412 | 3 | 3 | 3 | 0 | 0 | 0 |
| Other Materials | 0.0742 | 0.0685 | 0.0704 | 4 | 5 | 6 | 1 | 4 | 1 |
| Real Estate | 0.0412 | 0.0470 | 0.0454 | 9 | 9 | 10 | 0 | 1 | 1 |
| Telecommunication Services | 0.0258 | 0.0225 | 0.0222 | 13 | 12 | 12 | 1 | 1 | 0 |
| Transportation | 0.0642 | 0.0785 | 0.0805 | 6 | 4 | 4 | 4 | 4 | 0 |
| Utilities | 0.0444 | 0.0456 | 0.0459 | 8 | 10 | 9 | 4 | 1 | 1 |
| | | | | | | | 28 | 28 | 4 |
| | | | | | | ***n*** | 14 | 14 | 14 |
| | | | | | | ***r*** | 0.938 | 0.938 | 0.991 |
| | | | | | | ***t*** | 9.4125 | 9.4125 | 25.9521 |
| | | | | | | ***critical value 95%*** | 2.179 | 2.179 | 2.179 |
| | | | | | | ***critical value 99%*** | 3.055 | 3.055 | 3.055 |
| | | | | | | ***significance*** | ** | ** | ** |

* denotes significance at the 95% confidence level
** denotes significance at the 99% confidence level

In some industries there is a noticeable difference in CVaR between the approaches. For example in Diversified Financials, the parametric approach gives a much lower CVaR than either of the other approaches. In most of the other industries there is similarity in rankings between the approaches. Similarities are found to be significant at the 95% level, and hence we reject the null hypothesis of no association between the approaches for the Transition model.

The *t* scores shown in Table 4-32 show that the greatest association occurs between our Analytical model and the Monte Carlo approach. We therefore put forward that our Analytical model is a viable alternative to the Monte Carlo approach in that it gives significantly similar outcomes, but is far less complex and less modelling intensive. In discussing the differences between their Monte Carlo and standard (based on current ratings) VaR approaches, Creditmetrics (Gupton et al., 1997) state that the standard or 'analytical' (estimates computed directly from formulas) approach has the advantages of speed and precision (no random noise introduced). They state that the disadvantages are for larger portfolios where speed is no longer true and that it limits the availability of statistics that can be estimated. These same observations will hold true for CVaR. Thus, a modeller's preference to use an analytical approach like ours or a Monte Carlo approach will depend on aspects such as the modeller's requirements for speed and the size of the portfolio.

## 4.5. Summary

There is found to be association between the industry rankings of the Structural and Equity Models. Both models rank Technology Hardware & Equipment and Software and Services, Pharmaceuticals & Biotechnology, Paper & Forest Products and Automobiles & Components at the high end of the risk scale. Industries found by both models to have a relatively low risk ranking include Diversified Financials, Real Estate, Utilities, Food Beverage & Tobacco, and Food and Staples Retailing. Relatively larger differences exist in rankings for Banks, Energy, Insurance, Retailing, and Telecommunications due to balance sheet structural differences. There is also found to be significant association between the CVaR rankings of the two models.

The Transition Model, which includes a lesser number of industries, ranked Healthcare as having the highest risk followed by Food Beverage & Tobacco and Other Consumer Discretionary. Lowest risk are Banks, Telecommunication Services, and Insurance.

Diversification results in a noticeable reduction in risk for all three of the models. Whilst diversification does result in some changes to industry rankings, all three models show significant association between undiversified and diversified industry rankings.

Within all three of the models, there is found to be significant association between parametric and nonparametric CVaR rankings, and between VaR and CVaR. For the Transition model, we compared the rankings of 3 CVaR methodologies (parametric, analytical and Monte Carlo), finding significant association between all 3 approaches, especially between the Monte Carlo and Analytical approach.

The Portfolio Contribution CVaR approach found Diversified Financials and Food Beverage and Tobacco to have the highest contribution to the CVaR portfolio. This approach is impacted by the size of the industry, which has no bearing on the other CVaR approaches.

For both the Structural and Equity models there is found to be no significant difference in industry VaR and CVaR rankings over time when using a 7 year rolling widow approach. When using a 1 year data time frame, there was found to be significant difference over time in VaR rankings.

Overall there is found to be significant association between all factors tested, with the exception of industry rankings over time using 1 year data tranches.

# 5. DEVELOPMENT OF SECTOR INDICES AND *i*Transition MODEL

## 5.1. Sector Indices

This study has developed specific measurements for each of our 3 models, as summarised in Sections 4.1 to 4.3. VaR has been calculated for each model on a diversified and undiversified basis. CVaR has been calculated using parametric and nonparametric methods. Besides just using risk measurements for capital adequacy purposes, banks use them for a number of other purposes such as risk concentration limits, setting policies, and allocating discretions to lending officers. Banks have traditionally obtained this information through their own or external macroeconomic research. The VaR and CVaR measurements we have provided can assist banks in this process by being able to identify the relative risk of Australian industries from both a credit and market perspective, or they can use the methodology to derive their own measurements.

Banks often group risk measurements into categories (such as high, medium, low) for simplicity. So for example, a lending officer may be given a higher lending discretion for a low risk industry than for a high risk one. Banks could use the actual VaR / CVaR measurements which we have provided (such as in the results summaries in Table 4-1, Table 4-2, and Table 4-3). Alternatively risk indices could be used, or risk categories (high, low, etc). In Table 5-1, we provide for all of these options. We have used the Equity model for market risk and the Structural model for credit risk (as Structural model provides a wider range of industries than the Transition model).

Table 5-1 *Risk Measurements, Indices and Categories*

The first column under each of the two models shows the industry. The second column for the Equity model shows the diversified VaR values which we have already calculated. The second column for the Structural model shows the diversified calibrated DD values, calculated from calibrated PD values (see column 8 of Table 4-2) using the inverse of the PD formula, i.e., –NORMSINV(PD). The third column of each model, the industry risk index, shows the relative risk of each industry to the mean, where 1 = average risk, > 1 = higher than average risk and < 1 = lower than average risk. The measurement is obtained by industry VaR divided by portfolio mean VaR.

| **Industry** | **Diversified Portfolio 95% VaR** | **Industry Risk Index** | **Relative Risk** | **Industry** | **Diversified Calibrated DD** | **Industry Risk Index** |
|---|---|---|---|---|---|---|
| Real Estate | 0.18495 | 0.63 | | Utilities | 6.0479 | 0.66 |
| Diversified Financials | 0.20082 | 0.69 | | Real Estate | 5.8497 | 0.68 |
| Food Beverage & Tobacco | 0.20220 | 0.69 | Low | Diversified Financials | 5.7671 | 0.69 |
| Utilities | 0.20349 | 0.69 | | Healthcare Equipment & Services | 4.9954 | 0.80 |
| Banks | 0.22305 | 0.76 | | Energy | 4.8574 | 0.82 |
| Healthcare Equipment & Services | 0.22731 | 0.78 | | Media | 4.8463 | 0.82 |
| Media | 0.23173 | 0.79 | | Food Beverage & Tobacco | 4.6621 | 0.86 |
| Capital Goods | 0.23692 | 0.81 | Medium-Low | Commercial Services & Supplies | 4.3721 | 0.91 |
| Commercial Services & Supplies | 0.24239 | 0.83 | | Capital Goods | 4.2415 | 0.94 |
| Transportation | 0.24384 | 0.83 | | Transportation | 4.1691 | 0.96 |
| Food & Staples Retailing | 0.24593 | 0.84 | | Hotels Restaurants & Leisure | 3.9993 | 1.00 |
| Retailing | 0.28206 | 0.96 | | Food & Staples Retailing | 3.9836 | 1.00 |
| Energy | 0.28578 | 0.98 | Medium | Construction Materials | 3.9196 | 1.02 |
| Automobiles & Components | 0.30102 | 1.03 | | Metals & Mining | 3.7598 | 1.06 |
| Chemicals | 0.31059 | 1.06 | | Pharmaceuticals & Biotechnology | 3.7317 | 1.07 |
| Hotels Restaurants & Leisure | 0.31481 | 1.07 | | Retailing | 3.5284 | 1.13 |
| Construction Materials | 0.31955 | 1.09 | | Consumer Durables & Apparel | 3.4796 | 1.15 |
| Insurance | 0.33763 | 1.15 | Medium-High | Chemicals | 3.3695 | 1.19 |
| Metals & Mining | 0.33825 | 1.15 | | Banks | 3.2089 | 1.25 |
| Telecommunication Services | 0.34548 | 1.18 | | Software & Services | 3.1412 | 1.27 |
| Paper & Forest Products | 0.36123 | 1.23 | | Paper & Forest Products | 3.0648 | 1.30 |
| Pharmaceuticals & Biotechnology | 0.37209 | 1.27 | | Automobiles & Components | 3.0470 | 1.31 |
| Consumer Durables & Apparel | 0.39006 | 1.33 | High | Telecommunication Services | 2.9682 | 1.35 |
| Software & Services | 0.43535 | 1.49 | | Technology Hardware & Equipment | 2.7533 | 1.45 |
| Technology Hardware & Equipment | 0.48570 | 1.66 | | Insurance | 2.1468 | 1.86 |

The industry risk measurement is useful in that it is very easy to tell the relative risk from the measurement (for example a measurement of 0.5 is an industry with half the average risk, and 2 is double the average). It also facilitates comparison between models and comparison between VaR and CVaR (if all of these have a relative index calculated). In column 3 we show the relative risk in categories of low (20th percentile), medium-low (>20$^{th}$ to 40$^{th}$ percentile), medium >40th - 60$^{th}$ percentile, medium-high (>60$^{th}$ – 80$^{th}$ percentile) and high (>80$^{th}$ percentile).

It may also be prudent for a user of VaR indices, such as banks, to bring CVaR into category allocation. An industry may have a relatively low VaR, but a high CVaR due to extreme loss potential. In Table 5-2 we use the Equity model to illustrate how this could be achieved. The same process could be applied to the other models.

Table 5-2 *Inclusion of CVaR Into Risk Category Allocation*

This table provides an example of risk categories, using the Equity model and diversified VaR and nonparametric CVaR values. The use of CVaR is a conservative measure focussing on the top end of the risk. Following this conservative focus, we have chosen the overall risk category as being the highest risk category between VaR and CVaR. So if an industry has a VaR risk of medium, but a CVaR risk of medium-high, it is allocated to the medium-high category. Thus, using this approach, the inclusion of CVaR results in a downward shift of risk categories towards the higher risk buckets.

| | Var | | | CVar | | | |
|---|---|---|---|---|---|---|---|
| **Industry** | **Daily Diversified Portfolio 95% VaR** | **Industry VaR Index** | **Var Risk Category** | **CVaR** | **Industry CVaR Index** | **CVaR Risk Category** | **Combined Risk Category** |
| Food Beverage & Tobacco | 0.0128 | 0.69 | Low | 0.0369 | 0.75 | Low | low |
| Utilities | 0.0129 | 0.69 | Low | 0.0351 | 0.71 | Low | low |
| Banks | 0.0141 | 0.76 | Low | 0.0268 | 0.54 | Low | low |
| Real Estate | 0.0117 | 0.63 | Low | 0.0381 | 0.77 | Medium-Low | medium-low |
| Diversified Financials | 0.0127 | 0.69 | Low | 0.0392 | 0.79 | Medium-Low | medium-low |
| Media | 0.0147 | 0.79 | Medium-Low | 0.0417 | 0.85 | Medium-Low | medium-low |
| Healthcare Equipment & Services | 0.0144 | 0.78 | Medium-Low | 0.0499 | 1.01 | Medium | medium |
| Capital Goods | 0.0150 | 0.81 | Medium-Low | 0.0428 | 0.87 | Medium | medium |
| Transportation | 0.0154 | 0.83 | Medium-Low | 0.0451 | 0.91 | Medium | medium |
| Food & Staples Retailing | 0.0156 | 0.84 | Medium | 0.0343 | 0.69 | Low | medium |
| Retailing | 0.0178 | 0.96 | Medium | 0.0469 | 0.95 | Medium | medium |
| Chemicals | 0.0196 | 1.06 | Medium | 0.0396 | 0.80 | Medium-Low | medium |
| Commercial Services & Supplies | 0.0153 | 0.83 | Medium-Low | 0.0530 | 1.07 | Medium-High | medium-high |
| Energy | 0.0181 | 0.98 | Medium | 0.0538 | 1.09 | Medium-High | medium-high |
| Automobiles & Components | 0.0190 | 1.03 | Medium | 0.0536 | 1.09 | Medium-High | medium-high |
| Hotels Restaurants & Leisure | 0.0199 | 1.07 | Medium-High | 0.0510 | 1.03 | Medium-High | medium-high |
| Construction Materials | 0.0202 | 1.09 | Medium-High | 0.0390 | 0.79 | Medium-Low | medium-high |
| Metals & Mining | 0.0214 | 1.15 | Medium-High | 0.0498 | 1.01 | Medium | medium-high |
| Telecommunication Services | 0.0219 | 1.18 | Medium-High | 0.0343 | 0.70 | Low | medium-high |
| Insurance | 0.0214 | 1.15 | Medium-High | 0.0586 | 1.19 | High | high |
| Paper & Forest Products | 0.0228 | 1.23 | High | 0.0653 | 1.32 | High | high |
| Pharmaceuticals & Biotechnology | 0.0235 | 1.27 | High | 0.0656 | 1.33 | High | high |
| Consumer Durables & Apparel | 0.0247 | 1.33 | High | 0.0506 | 1.03 | Medium-High | high |
| Software & Services | 0.0275 | 1.49 | High | 0.0862 | 1.75 | High | high |
| Technology Hardware & Equipment | 0.0307 | 1.66 | High | 0.0964 | 1.95 | High | high |

## 5.2. *i*Transition Model

The proposed *i*Transition model is based on a Transition Matrix. The CreditPortfolioView model described in Section 2.5.4.3 uses a Transition Matrix which incorporates empirically derived industry factors. CreditPortflolioView is based on the premise that transition probability of borrowers is not equal among borrowers of the same credit rating. Each transition probability is weighted by a factor, using variables such as GDP growth, unemployment rates and interest rates. As per APRA's findings discussed in Section 1.3.3 of the literature survey, Australian banks do not favour modelling approaches conditioned on the state of the economy, due to both economic forecasting difficulty and intensiveness of computer modelling.

The unconditional Transition Matrix is based on the average of historical transitions (using a Bank's own probabilities or those of an external rating agency such as S&P). Using the CreditPortfolioView framework, we incorporate industry factors into a Transition Matrix, but using factors derived from our Equity and Structural modelling, rather than economic factors. The probability of a loan (in this example a B rated loan) moving to another rating category will modified by industry factor $i$, as follows:

| | | | | |
|---|---|---|---|---|
| B | $\rho_{BAi}$ | $\rho_{BBi}$ | $\rho_{BCi}$ | $\rho_{BDi}$ |

For our example we have simplified the number of rating categories, but in reality the model allows for all ratings such as AAA, AA etc. The sum of all $\rho$'s in the row is 100%, thus capturing all states of probability.

This approach benefits banks by allowing the incorporation of industry factors, but without the intensive economic modelling and forecasting they do not favour. In doing this, the model follows the premise that not all borrowers of the same grade have an equal transition. It makes the assumption that it is not necessary to incorporate macroeconomic factors into the model, as relative industry risk and susceptibility to economic factors will be reflected in historical share price movements as measured by our market VaR indices.

We cannot, however, base the industry factors on share price movements alone as this is not the only component of credit risk. We therefore need to calculate the relationship between market and credit risk. Our Equity model measures market risk (VaR) and our Structural model measures credit risk (PD). *i*Transition measures relative industry risk as the relative impact on PD if the equity VaR were to materialise for each industry (i.e. losses equal to VaR). We have daily historical information for both the Equity and Structural models from which to calculate the association, i.e. if there is a 1% increase in equity VaR, what is the % increase in PD for a company in that industry? The model requires four steps.

Firstly, obtain transition probabilities ($\rho$) - we will use the Transition Matrix approach described in this study, based on S&P transition values.

Secondly, calculate an industry adjustment factor i for each industry using the relationship between market VaR and credit VaR for each industry. For example, assuming industry A has a VaR of 30%, as calculated by our Equity (market risk) model, what is the corresponding impact on the PD as calculated by our Structural (credit risk) model?

Thirdly, modify each transition probability using the factors calculated in step 2 above and the methodology described in Section 2.5.4.3 (i.e. weight each transition according to relative market risk).

Lastly, run the Transition model as per Section 3.4.3 to calculate VaR based on the revised transition probabilities.

Industry adjustment factors have been calculated for each of our industries and are shown in Table 5-3.

Table 5-3 *Industry Adjustment Factors*

The table shows key components of industry adjustments. The first column shows the equity VaR for each industry as calculated by our Equity model. The second column shows the associated standard deviation (VaR/1.645 at 95% confidence level from standard statistical tables). The third column shows the asset standard deviation as calculated by our Structural model. Column 4 shows the industry adjustment factor *i*, the calculation of which is described immediately following the table.

| **Industry** | **Equity VaR** | **Equity Weighted Standard Deviation** | **Structural Weighted Asset Standard Deviation** | ***i*** |
|---|---|---|---|---|
| Banks | 0.3030 | 0.1842 | 0.0278 | 0.5237 |
| Diversified Financials | 0.4145 | 0.2520 | 0.0828 | 1.6070 |
| Energy | 0.5904 | 0.3589 | 0.2811 | 1.4380 |
| Food Beverage & Tobacco | 0.3987 | 0.2424 | 0.1503 | 0.7945 |
| Healthcare | 0.6008 | 0.3652 | 0.2813 | 1.1641 |
| Insurance | 0.5366 | 0.3262 | 0.0938 | 0.3548 |
| Media | 0.4561 | 0.2773 | 0.1898 | 1.0662 |
| Metals & Mining | 0.5595 | 0.3401 | 0.2570 | 1.0038 |
| Other Consumer Discretionary | 0.5154 | 0.3133 | 0.2377 | 0.9578 |
| Other Materials | 0.4662 | 0.2834 | 0.2093 | 0.8263 |
| Real Estate | 0.3931 | 0.2390 | 0.1520 | 1.1948 |
| Telecommunication Services | 0.3640 | 0.2213 | 0.1565 | 0.7675 |
| Transportation | 0.4732 | 0.2877 | 0.1643 | 0.7176 |
| Utilities | 0.3777 | 0.2296 | 0.1201 | 1.5839 |

The calculation of the industry adjustment factor *i*, is illustrated by the following example: Consider the case of the Utilities industry which has an equity VaR of 37.8%. The question is that if VaR materialised (i.e. we were to see a reduction of 37.8% in equity values), what impact would this have on the asset values in our credit model, and how would this in turn impact on the PD? We see from our table above that this VaR corresponds to a 12% asset standard deviation (or VaR of 19.75%) over the same period. To calculate *i* we commence by substituting the reduced asset values should VaR materialise (i.e. loss of 19.75%) into DD and PD formulae, using the methodology described in Section 3.4.2., and then calculating the percentage difference between the original PD values and revised PD values. As per the discussion on CreditPortfolioView in Section 2.5.4.3, an industry with i > 1, has higher risk than the norm and i < 1 = lower risk. To achieve this position, we calculate the change in PD for the particular industry ($PD_a$) relative to the average change in PD for all industries in the portfolio ($PD_p$):

$$i = \frac{\Delta PD_a}{\Delta PD_p} \tag{5-1}$$

Let us consider Banks and Diversified Financials as another example. Both industries have low equity, and thus have a very short distance to default in terms of our Structural model. Thus movements in equity affect these industries more than other industries. However Banks have a very low asset volatility (standard deviation of 2.78%) compared to Diversified Financials (standard deviation of 8.3%). Thus, due to this higher volatility, Diversified Financials have a much higher *i* than Banks. However, neither of these two industries will have a significant impact on VaR under the *i*Transition model as compared to an unconditional approach, as the bulk of assets for both industries are in the AA and above categories which have a very small impact on any changes to the probability matrix as per the comments under Table 5-4.

Thus for our model, all you need to know to calculate *i* is VaR and the relationship between VaR and PD for each industry, as opposed to undertaking a macroeconomic analysis. Based on the mix of industries in our matrix, PD factors are adjusted as per Table 5-4.

Table 5-4 *Weighted Category Adjustments*

The table shows the industry adjustment factors for each rating class. This is the weighted average of the *i*'s for each borrower in the rating category.

| **Rating** | *i* |
|---|---|
| AAA | 1.38 |
| AA | 0.60 |
| A | 1.07 |
| BBB | 1.08 |
| BB | 1.23 |
| B | 1.09 |
| CCC/C | 1.00 |
| D | 1.00 |

AAA and BB categories > 1 is due to high weightings in these categories of Diversified Financial assets with *i* of 1.6 as per Table 5-3. AA category < 1 is due to high weighting of Bank assets with *i* of 0.52. A, BBB and B are close to 1 due a diversified asset mix. C through to D = 1 as there are no assets in our portfolio in these categories.

In practice, neither the AAA or the AA assets will have any material impact on the probability matrix, as their PD is so close to zero, that any additional weighting has almost no impact on overall VaR (i.e. even a 100% change in a PD close to zero results in a PD which is still close to zero).

Table 5-5 shows the revised probability matrix.

Table 5-5 *Revised iTransition Probability Matrix*

Using the weightings in Table 5.4, we recalculate the original probability matrix in Table 3-4 as per the methodology in Section 2.5.4.3. Essentially, we recalculate the PD factor in column D of the matrix, and then using reverse linear regression we re-calibrate the remainder of the categories so each row = 1.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| **AAA** | 91.64% | 7.72% | 0.48% | 0.09% | 0.06% | 0.00% | 0.00% | 0.00% |
| **AA** | 0.63% | 90.44% | 8.12% | 0.61% | 0.06% | 0.11% | 0.02% | 0.01% |
| **A** | 0.05% | 2.15% | 91.32% | 5.78% | 0.45% | 0.17% | 0.03% | 0.04% |
| **BBB** | 0.02% | 0.22% | 4.10% | 89.62% | 4.68% | 0.82% | 0.20% | 0.33% |
| **BB** | 0.04% | 0.09% | 0.36% | 5.78% | 83.01% | 8.07% | 1.03% | 1.63% |
| **B** | 0.00% | 0.08% | 0.22% | 0.31% | 5.84% | 81.75% | 4.74% | 7.05% |
| **CCC/C** | 0.09% | 0.00% | 0.35% | 0.45% | 1.50% | 11.13% | 53.53% | 32.95% |

When comparing to the unconditional matrix in Table 3-4 and Transition Worksheet 3 of Appendix 4, we note that inclusion of our *i* factors has only had a noticeable change in categories BBB through B. As 85% of our portfolio is A and above, we can expect very little difference in VaR between the conditional and unconditional models. Naturally, a portfolio with higher weightings in other industries and rating categories would achieve a different result. The results of our conditional model are summarised in Table 5-6, and comparison to unconditional results is provided in Table 5-7.

Table 5-6 *Results of iTransition Model*

This table follows the same format as the results for the unconditional model presented in Table 4-3, but uses the conditional probability matrix in Table 5-5.

| **Industry** | **Number of Companies** | **Debt ($m)** | **Undiversified Standard Deviation** | **Undiversified 95% VaR** | **Diversified Standard Deviation** | **Diversified Portfolio 95% VaR** | **CVaR Parametric** | **CVaR Analytical** |
|---|---|---|---|---|---|---|---|---|
| Banks | 37 | 401,070 | 0.0080 | 0.0131 | 0.0070 | 0.0114 | 0.0165 | 0.0126 |
| Diversified Financials | 42 | 82,029 | 0.0179 | 0.0294 | 0.0084 | 0.0138 | 0.0369 | 0.0715 |
| Energy | 7 | 5,935 | 0.0317 | 0.0521 | 0.0284 | 0.0467 | 0.0653 | 0.0607 |
| Food Beverage & Tobacco | 16 | 21,685 | 0.0467 | 0.0768 | 0.0307 | 0.0506 | 0.0963 | 0.1867 |
| Healthcare | 5 | 1,388 | 0.0615 | 0.1012 | 0.0611 | 0.1005 | 0.1269 | 0.1772 |
| Insurance | 33 | 12,046 | 0.0125 | 0.0205 | 0.0092 | 0.0151 | 0.0257 | 0.0239 |
| Media | 5 | 22,589 | 0.0336 | 0.0552 | 0.0267 | 0.0439 | 0.0692 | 0.0732 |
| Metals & Mining | 7 | 30,827 | 0.0127 | 0.0209 | 0.0109 | 0.0180 | 0.0262 | 0.0214 |
| Other Consumer Discretionary | 5 | 2,275 | 0.0466 | 0.0767 | 0.0312 | 0.0513 | 0.0962 | 0.1499 |
| Other Materials | 8 | 10,068 | 0.0371 | 0.0610 | 0.0371 | 0.0610 | 0.0764 | 0.0726 |
| Real Estate | 13 | 14,065 | 0.0204 | 0.0335 | 0.0139 | 0.0229 | 0.0420 | 0.0479 |
| Telecommunication Services | 6 | 34,643 | 0.0124 | 0.0204 | 0.0094 | 0.0155 | 0.0256 | 0.0227 |
| Transportation | 22 | 28,891 | 0.0321 | 0.0528 | 0.0262 | 0.0431 | 0.0661 | 0.0834 |
| Utilities | 35 | 40,923 | 0.0219 | 0.0360 | 0.0171 | 0.0282 | 0.0452 | 0.0472 |
| Total | 241 | 708,435 | 0.0145 | 0.0239 | 0.0074 | 0.0121 | 0.0299 | 0.0354 |

Table 5-7 *Comparison of Conditional and Unconditional Outcomes*

The table compares results for a range of metrics for each industry using the unconditional probability matrix in Table 3-4 to the *i*Transition conditional probability matrix in Table 5-5.

| | **Unconditional** | **Conditional on *i*** |
|---|---|---|
| Undiversified Standard Deviation | 0.0147 | 0.0145 |
| Undiversified 95% VaR | 0.0242 | 0.0239 |
| Diversified Standard Deviation | 0.0076 | 0.0074 |
| Diversified Portfolio 95% VaR | 0.0124 | 0.0121 |
| CVaR Parametric | 0.0304 | 0.0299 |
| CVaR Analytical | 0.0342 | 0.0354 |

Overall, VaR has reduced slightly due to the reduced risk in the AA category (60% of portfolio, mainly due to the high weighting of Banks). Nonparametric CVaR has increased slightly. This is to be expected, as CVaR represents the riskiest end of the portfolio and Table 5-4 shows increased *i* weighting in categories from A downwards.

## 5.3. Summary

Banks use risk measurements for a several purposes besides capital allocation, such as risk concentration limits, setting policies, and allocating discretions to lending officers. Banks have traditionally obtained this information through their own or external macroeconomic research. Through our market and credit modelling, we have provided banks with risk indices which can be used to identify the relative risk of Australian industries, or they can use the methodology to derive their own measurements.

Indices have been calibrated to 1, where a ranking of 1 = average risk, a ranking > 1 = higher than average risk, and a ranking < 1 = lower than average risk. These have been grouped into buckets of low, medium low, medium, medium high and high risk.

Our methodology allows for industries to be categorised on VaR alone, or for CVaR to be incorporated into the risk categorisation.

A new model, *i*Transition, has been developed to allow incorporation of industry factors into a Transition model, without the need for macroeconomic analysis that banks do not favour.

Our Equity and Structural modelling has shown an association between credit and market industry risk, i.e. the same industries that are risky from a market perspective are also risky from a credit perspective. Based on this relationship, the model makes the assumption that it is not necessary to incorporate macroeconomic factors into the model, as relative industry risk and susceptibility to economic factors will be reflected in historical share price movements as measured by our market VaR indices and the their relative impact on PD. Therefore all you need to calculate industry risk adjustment factors is market VaR and a VaR-PD relationship factor.

We have used S&P transition values in our model. An industry adjustment factor *i* has been calculated for each industry, based on equity VaR and the impact that equity movements have on PD using the relationship between market VaR and credit VaR for each industry. Equity VaR is calculated by our market model, and the impact on PD is calculated by the impact of equity movements on asset values (as measured by our Structural model), and incorporating these revised asset values into DD and PD formulas (as used in our Structural model). The adjustment factor $i$ is calibrated to 1 so that 1= average industry risk, a factor > 1 = above average industry risk, and a factor < 1 = below average industry risk.

Once transition probabilities are modified by $i$ to provide a conditional probability matrix, we re-run our Transition model to calculate new VaR and CVaR values.

For our Australian portfolio, there was very little movement in conditional results. This is because industries with $i$ significantly different to 1, in our portfolio, have a high percentage of entities in categories A and above. These entities have a PD very close to zero, and additional weightings (up or down) still result in a PD close to zero, with little impact on VaR. A portfolio with higher weightings in other industries and rating categories would achieve a different result.

# 6. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

In this section we will commence by summarising the key benefits that the study will provide to banks and other modellers. We will then examine each of the original objectives of the study to see the extent to which these have been met, and the conclusions that can be made in relation to the particular aspects of the study addressed by each objective. Finally recommendations for further research will be made.

## 6.1. Benefits and Original Contributions of the Study

The study addresses some important needs and provides some significant benefits to banks and other market and credit modellers. This includes enhancing understanding of VaR, CVaR and industry risk, as well as providing new modelling methodologies.

VaR is an increasingly important field of study with the advent of Basel II, and the study provides detailed insight into the topic. This includes analysis of a range of VaR and CVaR metrics, spanning both credit and market risk. In particular, there is a lack of existing research in Australian market, which is a void addressed by the study, through extensive analysis of industry risk.

CVaR is still in its infancy in the market and credit areas, but is gaining momentum, and this research contributes to the body of knowledge in this area. The study has examined a range of CVaR techniques for each of the models, including parametric and nonparametric, as well as Monte Carlo modelling. Original methodology has been developed, such as CStdev, CDD and CPD for the Structural model and analytical CVaR for the Transition model.

The study has also developed the original *i*Transition model, which allows incorporation of industry factors into a Transition Matrix without the need for macroeconomic analysis.

Industry overconcentration is a key reason for difficulties experienced by banks and can ultimately contribute to bank failure. Understanding of industry risk is crucial to banks to effectively manage their risk profile. APRA has shown that Australian banks do not favour macroeconomic modelling. The information and tools examined and provided in this study are not just important in respect of Basel II, but also provide methodology for measuring industry market and credit risk without the need for macroeconomic analysis. This can assist banks with several aspects of risk management such as capital allocation, determining risk concentration limits, pricing or allocating discretionary lending authorities according to industry risk.

The study has also established an important link between credit and market risk, which can provide a springboard for the development of further models integrating these aspects.

## 6.2. Meeting of Objectives

### *6.2.1. To provide an analysis of industry VaR and CVaR in Australia and to compare model outcomes using a range of metrics.*

This section relates to objectives 1 – 3. Objective 1 was to provide an analysis of industry VaR in Australia. Objective 2 was to provide an analysis of CVaR in Australia. Objective 3 was to compare outcomes across models, over time, between correlated (diversified) and non-diversified data and between parametric and nonparametric CVaR.

A thorough analysis of industry VaR has been undertaken, using each of the three models. This has included an analysis of the outputs of each model, a comparison between the Structural and Equity models, an analysis over time using both 1 year and 7 year windows, a diversified and undiversified VaR comparison, and comparison of several CVaR methods.

Overall, we find the Technology Sectors to show the highest risk, and lowest risk in the Financial and Utility Sectors.

For all of the models, there is found to be significant association in industry rankings between diversified and undiversified VaR. The Equity and Structural models both show significant ranking correlation over time using a 7 year rolling window approach. When 1 year data frames are used, no association over time was found. This highlights the importance of using both short and long time frames in order to span different economic cycles as well as consider current conditions.

Significant association was found between the Equity and Structural models across a broad range of metrics (VaR, CVaR, PD, CPD, diversified / undiversified, parametric / nonparametric), which shows that the same industries that are risky from a market perspective are also risky from a credit perspective. All 3 models also show association within the model between the various parametric and nonparametric CVaR methodologies. The association across this range of metrics, including the CPD methodology developed by this study, highlights the robustness and consistency of these methods in measuring relative industry risk, a critical component of credit and market risk measurement.

### *6.2.2. To develop market and credit industry indices and new modelling techniques*

This section deals with objectives 4 – 6. Objective 4 is to derive specific measurements for VaR and CVaR for each industry and a set of relative market and credit industry indices, which can be incorporated into banks' models. Objective 5 is to develop new modelling techniques, where existing methodologies or data limitations do not readily permit the Industry VaR and CVaR analysis undertaken in this study. Objective 6 is to develop a new Credit VaR and CVaR model using Australian data (but with a universally applicable framework) which includes key elements of the Transition Matrix approach reviewed in this study and incorporates industry indices.

The study has developed specific industry indices for both credit and market VaR, based on the modelling done in this study. In addition to raw indices, the study has developed buckets of low, medium-low, medium, medium-high, and high risk, which permit the incorporation of VaR and CVaR. This methodology provides banks with a ready method for incorporating the indices into their policies, for example high risk industries could be restricted to a lower percentage of the portfolio than low risk industries, and lending officers could receive a higher discretion for low risk industries than for high ones.

New modelling techniques include Structural CStdev, CDD and CPD, calibration methodology for PD to EDF values, and the incorporation of Analytical CVaR into Transition modelling. The new CVaR techniques have shown significant association in industry rankings with existing CVaR and VaR methodology. This shows these techniques to be robust and viable alternatives to existing methodology. The Analytical CVaR method has produced significantly similar results to much more complex methodology such as Monte Carlo. This provides banks with a much simpler CVaR alternative. Selection of the most appropriate methodology will depend on the need for speed and taking into account size and complexity of the portfolio.

The *i*Transition model is also new methodology. We have already discussed how this allows banks to measure industry risk without the need for the macroeconomic analysis they do not favour.

The study has shown that whilst the majority of businesses are small businesses, by value large Corporates have the major share of the borrower market. As the entities in this study represent more than 90% of the ASX market capitalisation, listed companies provide a good reflection of industry risk by value. Banks could calculate $i$ from listed companies, where data is readily accessible, and apply it to Transitional modelling across their database. As some Structural data such as liabilities is static (available annually), PD can only be calculated once a year. But once the relationship between PD and VaR is established, $i$ can be updated on a daily basis, with movements in equity. The benefit is that this allows banks to re-calculate industry risk daily, ensuring their indices are always right up to date.

Whilst the new modelling techniques have been developed using Australian data, each of them is universally applicable, thus contributing to the international body of methodology.

### *6.2.3. To identify key limitations of the models*

This section relates to objective 7 which is to identify any key limitations of the models in an Australian context, such as availability of data.

The key limitation found in this study is the accessibility of data. A primary requirement of credit modelling is access to data. For the Equity and Structural models, data was publicly available for this study. However, it should be noted that unless the modeller has access to private data, these models are restricted to public companies.

The Structural model requires balance sheet data. Whilst historical debt and asset data is not available, this is not required for the model. The whole premise of the model is measuring the distance to the current default (debt) point based on the current value of the firm and the historical volatility of assets (measured using a combination of current balance sheet data, and historical equity values).

The data limitations of the Transition model stem from the fact that there are only a small number of public rated companies. In order to obtain sufficient data for this study, a number of sources has to be accessed, including direct provision of information by Moody's and S&P.

Whilst private data is available from sources such as KMV and ratings providers, this is usually by subscription which can be prohibitively expensive.

These data limitations do not affect banks however, as they have their own databases from which to obtain information.

Other limitations with VaR are the undesirable properties discussed in Section 2.4.5. including subadditivity, translation invariance, positive homogeneity, and monotonicity. These problems are not apparent with CVaR. We have also noted in Section 4.3 that the parametric VaR approach has some limitations (which will also apply to parametric CVaR). As it is based on a normal distribution, it can underestimate the VaR for portfolios that in reality have a fat tail, or overestimate VaR for those with a thin tail. An example was for our Banking portfolio where the parametric approach estimated 95% VaR beyond the actual nonparametric CVaR.

### *6.2.4. Concluding Remarks on Objectives*

Overall, the discussion shows that all original objectives have been met. Extensive modelling has been undertaken on VaR and CVaR, using a variety of metrics, enabling the robustness of the models to be tested, as well as providing a comprehensive picture of market and credit risk in Australia. Data limitations have been identified and compensated for. Industry indices have been formulated and new universally applicable VaR and CVAR techniques developed. These provide significant benefits to banks, such as simpler alternatives, and methodology for modelling and measuring industry risk without the need for the macroeconomic analysis they do not favour.

## 6.3. Recommendations for Further Research

The findings of this study and the new metrics introduced, coupled with the increased momentum in risk modelling brought about by the Basel II Accord and the relative lack of VaR and CVaR studies in Australia, provide significant scope for additional studies on both market and credit VaR and CVaR. CVaR in particular, due to its relative newness to the fields of market and credit risk, is a topic worthy of further study. Suggestions for further studies include the application of the metrics introduced by this study to other (international) data sets, the development of CVaR metrics for other credit or market models not included in this study, examination of whether of industry (*i*) factor adjustments can be applied to other credit models, and a study on the relative merits of the use of macroeconomic factors compared to industry VaR as measures of industry risk.

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# 7. APPENDICES

# Appendix 1. Models

Two models have been created in Microsoft Excel. Due to some common functionality between the Equity and Structural models, these have been integrated into one model. The Transition model has been separately developed.

The Integrated Equity and Structural models contain approximately 55 integrated worksheets, powered by 51 macros. Completed analysis of data within the model has a 'word count' of 20 million.

The Transition model contains approximately 40 worksheets, powered by 14 macros. Completed analysis of data within the model has a 'word count' of 11 million.

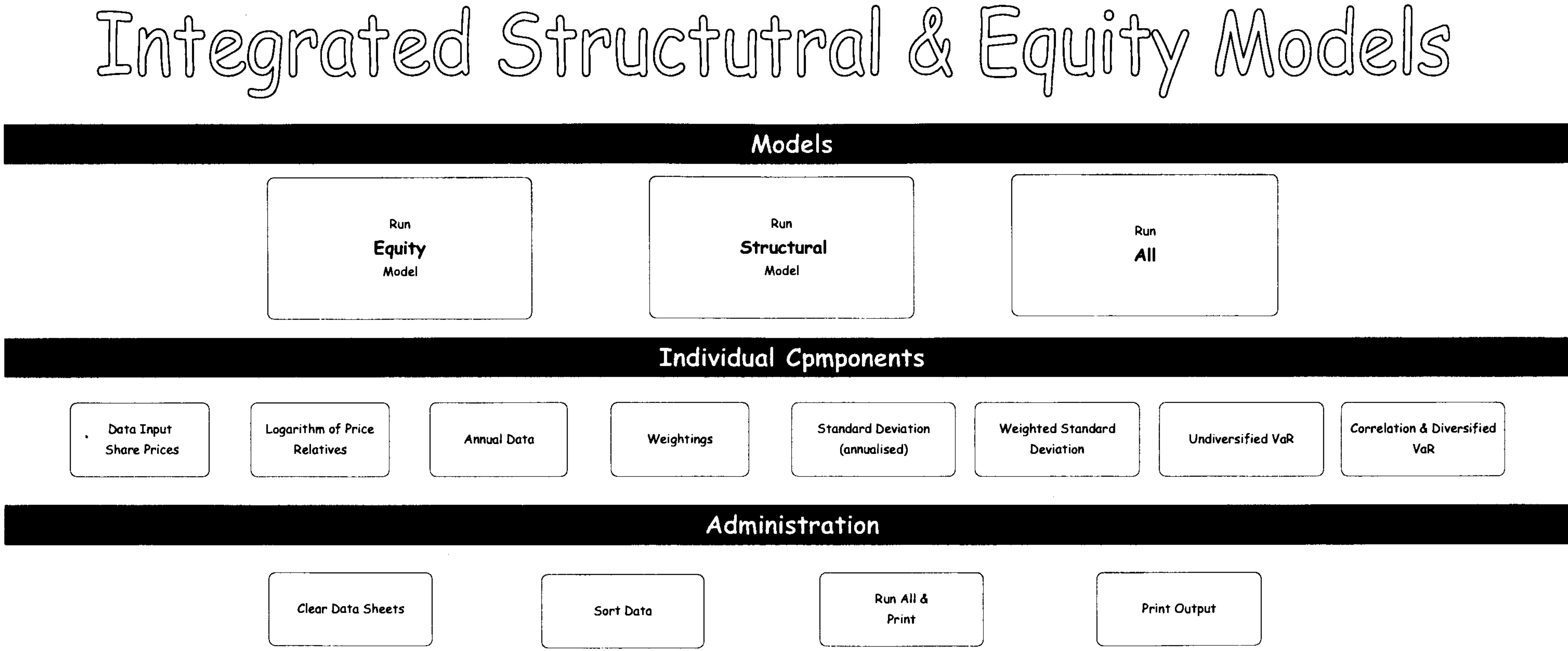
The macros have been grouped to buttons allow individual components of the model to run separately, or to allow the whole model to run with one press of a button. These buttons are shown on the following two pages.

Worksheets for each of the models are contained in Appendix 2 through to Appendix 6. Not all the worksheets are shown in the Appendices as the summarised output results and hypothesis testing have already been presented within the body of the study. Appendix 2 contains the Equity model which also includes the worksheets in common with the Structural Model. Appendix 3 contains only the worksheets unique to the structural model. Appendix 4 contains the Transition model worksheets.

Summaries of the worksheets, cross referenced to each worksheet number and page number, are provided at the front of each Appendix. We have used sample data from the Banking industry for these worksheets. As we are only providing a sample of a small part of one industry, and the study incorporates 25 industries with 15 years of daily data, the worksheets only provide a fraction of total data analysed the study (our summaries presented have a 'word count' of 50,000 representing 0.16% of the total analysis).

Nonetheless, the worksheets present a fairly comprehensive picture of the methodology used.

## Appendix 1 continued. Models



# Transition Model

## Models

- Transition
- /Transition
- All

## Individual Components & Administration

- Correlated Var
- Cvar Undiversified Actual
- Random Numbers
- Monte Carlo Ratings
- Cvar Monte Carlo
- Print

# Appendix 2. Equity Model

## Worksheet Structure

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 1 Price Data Sample

The worksheet shows the daily price index of each entity as obtained from Datastream. This is only a very small data sample as the complete database includes 15 years of daily data for all the industries.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30/06/2006 | 324.5 | 3770.3 | 741.2 | 405.7 | 693.9 | 543.7 | 250 | 2192.9 | 571.4 | 505.9 | 1403.9 | 984.7 | 385.2 |
| 29/06/2006 | 330 | 3715 | 733.7 | 406.3 | 685.9 | 554.8 | 247.1 | 2170.5 | 572.6 | 498 | 1372.7 | 966.5 | 385.2 |
| 28/06/2006 | 328.7 | 3676.7 | 730.6 | 390.3 | 676.4 | 554.8 | 248 | 2144.9 | 589.3 | 493.3 | 1375.6 | 949.6 | 385.2 |
| 27/06/2006 | 331.7 | 3715 | 739 | 405.7 | 680.6 | 558.4 | 245.1 | 2144.9 | 589.3 | 493.3 | 1385.7 | 949.6 | 377.8 |
| 26/06/2006 | 335.5 | 3693.7 | 724.7 | 401.6 | 675 | 573.2 | 246.1 | 2143 | 583.3 | 491.6 | 1385.7 | 945.8 | 370 |
| 23/06/2006 | 327.5 | 3681 | 722.6 | 402.9 | 678.1 | 556.6 | 249 | 2161.7 | 577.4 | 489.9 | 1370.5 | 950.4 | 366.7 |
| 22/06/2006 | 335.5 | 3722.1 | 741.2 | 405.7 | 676.4 | 551.1 | 244.1 | 2171.1 | 577.4 | 494.7 | 1382.1 | 952.1 | 362.6 |
| 21/06/2006 | 328.7 | 3601.6 | 725.3 | 405.4 | 657.7 | 536.3 | 244.1 | 2120.6 | 577.4 | 486.9 | 1374.1 | 932.7 | 361.1 |
| 20/06/2006 | 328 | 3586 | 717.3 | 393.1 | 646.9 | 541.8 | 243.1 | 2078.8 | 565.5 | 484 | 1360.3 | 924.2 | 351.9 |
| 19/06/2006 | 324.2 | 3571.8 | 717.3 | 390.3 | 656.3 | 541.8 | 243.1 | 2121.8 | 571.4 | 484.7 | 1361.1 | 925.9 | 351.9 |
| 16/06/2006 | 323.7 | 3604.4 | 714.7 | 399.4 | 663.3 | 541.8 | 244.1 | 2148.6 | 563.1 | 490.7 | 1371.2 | 931 | 342.6 |
| 15/06/2006 | 315.2 | 3580.3 | 703.6 | 394.7 | 656.3 | 530.7 | 240.2 | 2117.5 | 563.1 | 486.1 | 1353.8 | 920 | 341.5 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 2 Logarithm of Price Relatives

Daily returns are calculated from the data in Equity Worksheet 1 using the logarithm of the ratio of price relatives, obtained by using the formula ($P_t$ / $P_{t-1}$) as described in Section 2.4.2.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30/06/2006 | 0.003947 | 0.010363 | 0.004234 | 0.040176 | 0.013947 | 0.000000 | -0.003636 | 0.011865 | -0.028748 | 0.009483 | -0.002110 | 0.017640 | 0 |
| 29/06/2006 | -0.009085 | -0.010363 | -0.011432 | -0.038698 | -0.006190 | -0.006468 | 0.011762 | 0.000000 | 0.000000 | 0.000000 | -0.007315 | 0.000000 | 0.01939772 |
| 28/06/2006 | -0.011391 | 0.005750 | 0.019540 | 0.010157 | 0.008262 | -0.026159 | -0.004072 | 0.000886 | 0.010234 | 0.003452 | 0.000000 | 0.004010 | 0.02086195 |
| 27/06/2006 | 0.024134 | 0.003444 | 0.002902 | -0.003232 | -0.004582 | 0.029388 | -0.011715 | -0.008688 | 0.010166 | 0.003464 | 0.011030 | -0.004852 | 0.00895893 |
| 26/06/2006 | -0.024134 | -0.011104 | -0.025415 | -0.006926 | 0.002510 | 0.009931 | 0.019875 | -0.004339 | 0.000000 | -0.009750 | -0.008428 | -0.001787 | 0.01124378 |
| 23/06/2006 | 0.020476 | 0.032910 | 0.021685 | 0.000740 | 0.028036 | 0.027223 | 0.000000 | 0.023535 | 0.000000 | 0.015893 | 0.005805 | 0.020586 | 0.00414537 |
| 22/06/2006 | 0.002132 | 0.004341 | 0.011091 | 0.030810 | 0.016557 | -0.010203 | 0.004105 | 0.019908 | 0.020825 | 0.005974 | 0.010094 | 0.009155 | 0.02580788 |
| 21/06/2006 | 0.011653 | 0.003968 | 0.000000 | 0.007148 | -0.014426 | 0.000000 | 0.000000 | -0.020474 | -0.010379 | -0.001445 | -0.000588 | -0.001838 | 0 |
| 20/06/2006 | 0.001543 | -0.009086 | 0.003631 | -0.023048 | -0.010609 | 0.000000 | -0.004105 | -0.012552 | 0.014632 | -0.012303 | -0.007393 | -0.005493 | 0.02678346 |
| 19/06/2006 | 0.026610 | 0.006709 | 0.015653 | 0.011837 | 0.010609 | 0.020700 | 0.016106 | 0.014580 | 0.000000 | 0.009419 | 0.012771 | 0.011886 | 0.00321591 |
| 16/06/2006 | 0.015023 | -0.011801 | 0.006845 | 0.034015 | -0.006985 | 0.024608 | -0.016106 | 0.001512 | -0.006373 | 0.001441 | 0.004813 | -0.006824 | 0 |
| 15/06/2006 | -0.008658 | -0.003912 | -0.011242 | -0.010690 | 0.001817 | -0.000579 | 0.000000 | -0.001512 | -0.002115 | -0.030434 | -0.006953 | -0.004631 | -0.0084561 |

## Appendix 2 continued. Equity Model – Sample (Banks)

### Equity Worksheet 3 Standard Deviation

This worksheet shows the standard deviation of the returns calculated in Equity Worksheet 2, for each of the nine 7 year rolling windows. The standard deviation is annualised by multiplying by $\sqrt{250}$, based on the usual estimate of the number of annual trading days.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.2099 | 0.1842 | 0.1999 | 0.2145 | 0.1737 | 0.2700 | 0.3512 | 0.1973 | 0.2078 | 0.1661 | 0.2011 | 0.1784 | 0.2172 |
| 2 | 0.2153 | 0.1986 | 0.1984 | 0.2108 | 0.1837 | 0.2669 | 0.3122 | 0.2069 | 0.2139 | 0.1701 | 0.2065 | 0.1933 | 0.2467 |
| 3 | 0.2171 | 0.2207 | 0.2054 | 0.2247 | 0.1911 | 0.2860 | | 0.2198 | 0.2122 | 0.1829 | 0.2112 | 0.2071 | 0.2461 |
| 4 | 0.2341 | 0.2387 | 0.2168 | 0.2356 | 0.2035 | 0.2969 | | 0.2282 | 0.2197 | 0.1888 | 0.2186 | 0.2188 | 0.2582 |
| 5 | 0.2445 | 0.2428 | 0.2254 | 0.2447 | 0.2021 | 0.3087 | | 0.2274 | 0.2204 | 0.2079 | 0.2086 | 0.2193 | 0.2603 |
| 6 | 0.2470 | 0.2381 | 0.2240 | 0.2469 | 0.1961 | | | 0.2187 | 0.2133 | 0.2100 | 0.2191 | 0.2153 | 0.2558 |
| 7 | 0.2477 | 0.2454 | 0.2160 | 0.2502 | 0.1928 | | | 0.2074 | 0.2213 | 0.2112 | 0.2235 | 0.2250 | 0.2615 |
| 8 | 0.2441 | 0.2503 | 0.2204 | 0.2411 | 0.1885 | | | 0.1966 | 0.2308 | 0.2100 | 0.2326 | 0.2274 | 0.2620 |
| 9 | 0.2457 | 0.2511 | 0.2100 | 0.2427 | 0.1801 | | | 0.1864 | 0.2303 | 0.2110 | 0.2301 | 0.2289 | 0.2237 |

## Appendix 2 continued. Variance-Covariance Method – Sample (Banks)

Equity Worksheet 4 Weightings

Each company in the industry is weighted by market capitalisation, for each of the nine 7 year rolling windows.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0060 | 0.2053 | 0.0064 | 0.0074 | 0.2420 | 0.0010 | 0.0013 | 0.2401 | 0.0004 | 0.0652 | 0.0459 | 0.1781 | 0.0009 |
| 2 | 0.0061 | 0.1920 | 0.0060 | 0.0064 | 0.2446 | 0.0006 | 0.0007 | 0.2455 | 0.0004 | 0.0673 | 0.0555 | 0.1740 | 0.0007 |
| 3 | 0.0054 | 0.1944 | 0.0061 | 0.0077 | 0.2380 | 0.0005 | | 0.2532 | 0.0004 | 0.0661 | 0.0465 | 0.1809 | 0.0008 |
| 4 | 0.0051 | 0.1794 | 0.0054 | 0.0067 | 0.2198 | 0.0004 | | 0.3047 | 0.0003 | 0.0645 | 0.0393 | 0.1736 | 0.0008 |
| 5 | 0.0043 | 0.1870 | 0.0045 | 0.0059 | 0.2253 | 0.0002 | | 0.3182 | 0.0004 | 0.0572 | 0.0403 | 0.1561 | 0.0007 |
| 6 | 0.0045 | 0.1811 | 0.0045 | 0.0057 | 0.2417 | | | 0.3014 | 0.0003 | 0.0522 | 0.0449 | 0.1631 | 0.0006 |
| 7 | 0.0037 | 0.1708 | 0.0042 | 0.0050 | 0.2614 | | | 0.3015 | 0.0003 | 0.0435 | 0.0373 | 0.1716 | 0.0005 |
| 8 | 0.0048 | 0.1521 | 0.0050 | 0.0067 | 0.2719 | | | 0.3251 | 0.0004 | 0.0464 | 0.0402 | 0.1470 | 0.0006 |
| 9 | 0.0057 | 0.1521 | 0.0058 | 0.0061 | 0.2422 | | | 0.3263 | 0.0004 | 0.0545 | 0.0395 | 0.1666 | 0.0006 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 5 Weighted Standard Deviation

The standard deviation for each entity, as obtained in Equity Worksheet 3, is multiplied by the weightings in Equity Worksheet 4.

| | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.1842 | 0.0013 | 0.0378 | 0.0013 | 0.0016 | 0.0420 | 0.0003 | 0.0004 | 0.0474 | 0.0001 | 0.0108 | 0.0092 | 0.0318 | 0.0002 |
| 2 | 0.1949 | 0.0013 | 0.0381 | 0.0012 | 0.0014 | 0.0449 | 0.0002 | 0.0002 | 0.0508 | 0.0001 | 0.0115 | 0.0115 | 0.0336 | 0.0002 |
| 3 | 0.2080 | 0.0012 | 0.0429 | 0.0013 | 0.0017 | 0.0455 | 0.0001 | | 0.0557 | 0.0001 | 0.0121 | 0.0098 | 0.0375 | 0.0002 |
| 4 | 0.2202 | 0.0012 | 0.0428 | 0.0012 | 0.0016 | 0.0447 | 0.0001 | | 0.0695 | 0.0001 | 0.0122 | 0.0086 | 0.0380 | 0.0002 |
| 5 | 0.2217 | 0.0011 | 0.0454 | 0.0010 | 0.0014 | 0.0455 | 0.0001 | | 0.0724 | 0.0001 | 0.0119 | 0.0084 | 0.0342 | 0.0002 |
| 6 | 0.2161 | 0.0011 | 0.0431 | 0.0010 | 0.0014 | 0.0474 | | | 0.0659 | 0.0001 | 0.0110 | 0.0098 | 0.0351 | 0.0001 |
| 7 | 0.2143 | 0.0009 | 0.0419 | 0.0009 | 0.0013 | 0.0504 | | | 0.0625 | 0.0001 | 0.0092 | 0.0083 | 0.0386 | 0.0001 |
| 8 | 0.2099 | 0.0012 | 0.0381 | 0.0011 | 0.0016 | 0.0513 | | | 0.0639 | 0.0001 | 0.0097 | 0.0093 | 0.0334 | 0.0002 |
| 9 | 0.2057 | 0.0014 | 0.0382 | 0.0012 | 0.0015 | 0.0436 | | | 0.0608 | 0.0001 | 0.0115 | 0.0091 | 0.0381 | 0.0001 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 6 Correlation Matrix

Correlation between all the entities in the industry is calculated as described in Section 2.6.1. The figures below show the correlation of each entity with each other. For example, we see from the table that the correlation of Bendigo Bank (Column 4) with Bank of Queensland (Column 3) is 0.2197. The table shows the correlation for the first of our nine rolling windows, and the process is repeated for all the other years.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 | Column 8 | Column 9 | Column 10 | Column 11 | Column 12 | Column 13 |
| Column 1 | 1.0000 | 0.1837 | 0.2562 | 0.2390 | 0.2057 | 0.0696 | 0.0128 | 0.1821 | 0.0449 | 0.1945 | 0.2247 | 0.1893 | 0.0661 |
| Column 2 | 0.1837 | 1.0000 | 0.1729 | 0.2115 | 0.5086 | 0.0394 | -0.0153 | 0.4638 | 0.0323 | 0.3013 | 0.3140 | 0.6376 | 0.0517 |
| Column 3 | 0.2562 | 0.1729 | 1.0000 | 0.2197 | 0.2149 | 0.0211 | -0.1094 | 0.1737 | 0.0105 | 0.1480 | 0.2076 | 0.1819 | 0.0509 |
| Column 4 | 0.2390 | 0.2115 | 0.2197 | 1.0000 | 0.2277 | 0.0056 | 0.0115 | 0.1998 | -0.0209 | 0.2296 | 0.2224 | 0.2072 | 0.0038 |
| Column 5 | 0.2057 | 0.5086 | 0.2149 | 0.2277 | 1.0000 | 0.0496 | -0.0271 | 0.5036 | 0.0478 | 0.3036 | 0.2744 | 0.5073 | 0.0472 |
| Column 6 | 0.0696 | 0.0394 | 0.0211 | 0.0056 | 0.0496 | 1.0000 | 0.0426 | 0.0585 | 0.0257 | 0.0329 | 0.0205 | 0.0325 | -0.0395 |
| Column 7 | 0.0128 | -0.0153 | -0.1094 | 0.0115 | -0.0271 | 0.0426 | 1.0000 | 0.0583 | -0.0810 | 0.0363 | 0.0203 | 0.0031 | -0.0031 |
| Column 8 | 0.1821 | 0.4638 | 0.1737 | 0.1998 | 0.5036 | 0.0585 | 0.0583 | 1.0000 | 0.0213 | 0.2546 | 0.2732 | 0.4452 | 0.0724 |
| Column 9 | 0.0449 | 0.0323 | 0.0105 | -0.0209 | 0.0478 | 0.0257 | -0.0810 | 0.0213 | 1.0000 | 0.0377 | 0.0459 | 0.0291 | 0.0027 |
| Column 10 | 0.1945 | 0.3013 | 0.1480 | 0.2296 | 0.3036 | 0.0329 | 0.0363 | 0.2546 | 0.0377 | 1.0000 | 0.2670 | 0.3375 | 0.0318 |
| Column 11 | 0.2247 | 0.3140 | 0.2076 | 0.2224 | 0.2744 | 0.0205 | 0.0203 | 0.2732 | 0.0459 | 0.2670 | 1.0000 | 0.2865 | 0.0539 |
| Column 12 | 0.1893 | 0.6376 | 0.1819 | 0.2072 | 0.5073 | 0.0325 | 0.0031 | 0.4452 | 0.0291 | 0.3375 | 0.2865 | 1.0000 | -0.0027 |
| Column 13 | 0.0661 | 0.0517 | 0.0509 | 0.0038 | 0.0472 | -0.0395 | -0.0031 | 0.0724 | 0.0027 | 0.0318 | 0.0539 | -0.0027 | 1.0000 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 7    Variance Matrix

The table shows the first of our nine 7 year rolling windows, compiled using standard deviation data from Equity Worksheet 3.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Column 1 | 0.2099 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 2 | 0.0000 | 0.1842 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 3 | 0.0000 | 0.0000 | 0.1999 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 4 | 0.0000 | 0.0000 | 0.0000 | 0.2145 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1737 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 6 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.2700 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 7 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.3512 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 8 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1973 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.2078 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1661 | 0.0000 | 0.0000 | 0.0000 |
| Column 11 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.2011 | 0.0000 | 0.0000 |
| Column 12 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1784 | 0.0000 |
| Column 13 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.2172 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 8 Variance Correlation Matrix

The variance matrix in Equity Worksheet 7 is multiplied with the correlation matrix in Equity Worksheet 6 using matrix multiplication as per Section 2.6.1.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Column 1 | 0.2099 | 0.0386 | 0.0538 | 0.0502 | 0.0432 | 0.0146 | 0.0027 | 0.0382 | 0.0094 | 0.0408 | 0.0472 | 0.0397 | 0.0139 |
| Column 2 | 0.0338 | 0.1842 | 0.0319 | 0.0390 | 0.0937 | 0.0073 | -0.0028 | 0.0854 | 0.0059 | 0.0555 | 0.0578 | 0.1175 | 0.0095 |
| Column 3 | 0.0512 | 0.0346 | 0.1999 | 0.0439 | 0.0430 | 0.0042 | -0.0219 | 0.0347 | 0.0021 | 0.0296 | 0.0415 | 0.0364 | 0.0102 |
| Column 4 | 0.0513 | 0.0454 | 0.0471 | 0.2145 | 0.0488 | 0.0012 | 0.0025 | 0.0429 | -0.0045 | 0.0492 | 0.0477 | 0.0444 | 0.0008 |
| Column 5 | 0.0357 | 0.0883 | 0.0373 | 0.0395 | 0.1737 | 0.0086 | -0.0047 | 0.0875 | 0.0083 | 0.0527 | 0.0476 | 0.0881 | 0.0082 |
| Column 6 | 0.0188 | 0.0106 | 0.0057 | 0.0015 | 0.0134 | 0.2700 | 0.0115 | 0.0158 | 0.0069 | 0.0089 | 0.0055 | 0.0088 | -0.0107 |
| Column 7 | 0.0045 | -0.0054 | -0.0384 | 0.0040 | -0.0095 | 0.0150 | 0.3512 | 0.0205 | -0.0284 | 0.0127 | 0.0071 | 0.0011 | -0.0011 |
| Column 8 | 0.0359 | 0.0915 | 0.0343 | 0.0394 | 0.0994 | 0.0115 | 0.0115 | 0.1973 | 0.0042 | 0.0502 | 0.0539 | 0.0878 | 0.0143 |
| Column 9 | 0.0093 | 0.0067 | 0.0022 | -0.0043 | 0.0099 | 0.0053 | -0.0168 | 0.0044 | 0.2078 | 0.0078 | 0.0095 | 0.0060 | 0.0006 |
| Column 10 | 0.0323 | 0.0500 | 0.0246 | 0.0381 | 0.0504 | 0.0055 | 0.0060 | 0.0423 | 0.0063 | 0.1661 | 0.0444 | 0.0561 | 0.0053 |
| Column 11 | 0.0452 | 0.0631 | 0.0417 | 0.0447 | 0.0552 | 0.0041 | 0.0041 | 0.0549 | 0.0092 | 0.0537 | 0.2011 | 0.0576 | 0.0108 |
| Column 12 | 0.0338 | 0.1138 | 0.0325 | 0.0370 | 0.0905 | 0.0058 | 0.0006 | 0.0794 | 0.0052 | 0.0602 | 0.0511 | 0.1784 | -0.0005 |
| Column 13 | 0.0144 | 0.0112 | 0.0110 | 0.0008 | 0.0103 | -0.0086 | -0.0007 | 0.0157 | 0.0006 | 0.0069 | 0.0117 | -0.0006 | 0.2172 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 9 Unweighted Variance Covariance Matrix

The variance matrix in Equity Worksheet 7 is multiplied with the variance correlation matrix in Equity Worksheet 8 using matrix multiplication as per Section 2.6.1.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Column 1 | 0.0441 | 0.0071 | 0.0107 | 0.0108 | 0.0075 | 0.0039 | 0.0009 | 0.0075 | 0.0020 | 0.0068 | 0.0095 | 0.0071 | 0.0030 |
| Column 2 | 0.0071 | 0.0339 | 0.0064 | 0.0084 | 0.0163 | 0.0020 | -0.0010 | 0.0169 | 0.0012 | 0.0092 | 0.0116 | 0.0210 | 0.0021 |
| Column 3 | 0.0107 | 0.0064 | 0.0399 | 0.0094 | 0.0075 | 0.0011 | -0.0077 | 0.0068 | 0.0004 | 0.0049 | 0.0083 | 0.0065 | 0.0022 |
| Column 4 | 0.0108 | 0.0084 | 0.0094 | 0.0460 | 0.0085 | 0.0003 | 0.0009 | 0.0085 | -0.0009 | 0.0082 | 0.0096 | 0.0079 | 0.0002 |
| Column 5 | 0.0075 | 0.0163 | 0.0075 | 0.0085 | 0.0302 | 0.0023 | -0.0017 | 0.0173 | 0.0017 | 0.0088 | 0.0096 | 0.0157 | 0.0018 |
| Column 6 | 0.0039 | 0.0020 | 0.0011 | 0.0003 | 0.0023 | 0.0729 | 0.0040 | 0.0031 | 0.0014 | 0.0015 | 0.0011 | 0.0016 | -0.0023 |
| Column 7 | 0.0009 | -0.0010 | -0.0077 | 0.0009 | -0.0017 | 0.0040 | 0.1233 | 0.0040 | -0.0059 | 0.0021 | 0.0014 | 0.0002 | -0.0002 |
| Column 8 | 0.0075 | 0.0169 | 0.0068 | 0.0085 | 0.0173 | 0.0031 | 0.0040 | 0.0389 | 0.0009 | 0.0083 | 0.0108 | 0.0157 | 0.0031 |
| Column 9 | 0.0020 | 0.0012 | 0.0004 | -0.0009 | 0.0017 | 0.0014 | -0.0059 | 0.0009 | 0.0432 | 0.0013 | 0.0019 | 0.0011 | 0.0001 |
| Column 10 | 0.0068 | 0.0092 | 0.0049 | 0.0082 | 0.0088 | 0.0015 | 0.0021 | 0.0083 | 0.0013 | 0.0276 | 0.0089 | 0.0100 | 0.0011 |
| Column 11 | 0.0095 | 0.0116 | 0.0083 | 0.0096 | 0.0096 | 0.0011 | 0.0014 | 0.0108 | 0.0019 | 0.0089 | 0.0404 | 0.0103 | 0.0024 |
| Column 12 | 0.0071 | 0.0210 | 0.0065 | 0.0079 | 0.0157 | 0.0016 | 0.0002 | 0.0157 | 0.0011 | 0.0100 | 0.0103 | 0.0318 | -0.0001 |
| Column 13 | 0.0030 | 0.0021 | 0.0022 | 0.0002 | 0.0018 | -0.0023 | -0.0002 | 0.0031 | 0.0001 | 0.0011 | 0.0024 | -0.0001 | 0.0472 |

## Appendix 2 continued. Equity Model – Sample (Banks)

### Equity Worksheet 10 Weighted Variance Covariance Matrix

The variance covariance matrix in Equity Worksheet 9 is multiplied with the weightings in Equity Worksheet 4 using matrix multiplication as per Section 2.6.1.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Column 1 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 2 | 0.0000 | 0.0014 | 0.0000 | 0.0000 | 0.0008 | 0.0000 | 0.0000 | 0.0008 | 0.0000 | 0.0001 | 0.0001 | 0.0008 | 0.0000 |
| Column 3 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 4 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 5 | 0.0000 | 0.0008 | 0.0000 | 0.0000 | 0.0018 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0001 | 0.0001 | 0.0007 | 0.0000 |
| Column 6 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 7 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 8 | 0.0000 | 0.0008 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0000 | 0.0022 | 0.0000 | 0.0001 | 0.0001 | 0.0007 | 0.0000 |
| Column 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Column 10 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0001 | 0.0000 | 0.0001 | 0.0000 |
| Column 11 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0001 | 0.0001 | 0.0000 |
| Column 12 | 0.0000 | 0.0008 | 0.0000 | 0.0000 | 0.0007 | 0.0000 | 0.0000 | 0.0007 | 0.0000 | 0.0001 | 0.0001 | 0.0010 | 0.0000 |
| Column 13 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 11 Summary Data: Undiversified VaR

Undiversified VaR is obtained for each entity by multiplying the standard deviation from Equity Worksheet 3 by 1.645 (as per normal distribution tables for 95% confidence level.)
The total portfolio VaR is the weighted portfolio Stdev from Equity Worksheet 5 multiplied by 1.645.

| | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Undiversified VaR | | | | | | | | | | | | | | |
| 1 | 0.3030 | 0.3454 | 0.3030 | 0.3288 | 0.3528 | 0.2857 | 0.4442 | 0.5777 | 0.3245 | 0.3419 | 0.2733 | 0.3308 | 0.2935 | 0.3574 |
| 2 | 0.3206 | 0.3541 | 0.3266 | 0.3264 | 0.3468 | 0.3021 | 0.4391 | 0.5136 | 0.3404 | 0.3519 | 0.2798 | 0.3396 | 0.3180 | 0.4058 |
| 3 | 0.3421 | 0.3571 | 0.3630 | 0.3379 | 0.3696 | 0.3144 | 0.4705 | | 0.3616 | 0.3491 | 0.3008 | 0.3475 | 0.3406 | 0.4048 |
| 4 | 0.3622 | 0.3851 | 0.3927 | 0.3566 | 0.3875 | 0.3347 | 0.4884 | | 0.3755 | 0.3615 | 0.3105 | 0.3597 | 0.3599 | 0.4248 |
| 5 | 0.3646 | 0.4022 | 0.3994 | 0.3708 | 0.4025 | 0.3325 | 0.5079 | | 0.3741 | 0.3625 | 0.3419 | 0.3432 | 0.3608 | 0.4282 |
| 6 | 0.3554 | 0.4063 | 0.3916 | 0.3684 | 0.4061 | 0.3225 | | | 0.3598 | 0.3509 | 0.3454 | 0.3604 | 0.3542 | 0.4208 |
| 7 | 0.3525 | 0.4074 | 0.4036 | 0.3553 | 0.4117 | 0.3171 | | | 0.3411 | 0.3641 | 0.3474 | 0.3676 | 0.3701 | 0.4301 |
| 8 | 0.3452 | 0.4016 | 0.4118 | 0.3625 | 0.3967 | 0.3101 | | | 0.3233 | 0.3797 | 0.3455 | 0.3826 | 0.3741 | 0.4310 |
| 9 | 0.3384 | 0.4042 | 0.4130 | 0.3454 | 0.3993 | 0.2963 | | | 0.3067 | 0.3788 | 0.3471 | 0.3785 | 0.3765 | 0.3680 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 12 Summary Data: Weighted Diversified Portfolio

The worksheet provides a summary of the diversified portfolio data for the industry. The values in the Weighted Variance Covariance matrix in Equity Worksheet 10 are multiplied with the weightings in Equity Worksheet 4 and then summed to form the portfolio variance. Portfolio standard deviation ($\sigma$) is the square root of the variance. Portfolio VaR at the 95% confidence level is $1.645\sigma$ and at the 99% level is $2.33\sigma$, as obtained from standard normal distribution tables.

| Year | Variance | Std Dev | 95% VaR | 99% VaR |
|---|---|---|---|---|
| 1 | 0.0184 | 0.1356 | 0.2231 | 0.3159 |
| 2 | 0.0203 | 0.1426 | 0.2346 | 0.3323 |
| 3 | 0.0239 | 0.1545 | 0.2542 | 0.3600 |
| 4 | 0.0280 | 0.1674 | 0.2754 | 0.3901 |
| 5 | 0.0284 | 0.1685 | 0.2772 | 0.3927 |
| 6 | 0.0264 | 0.1626 | 0.2674 | 0.3788 |
| 7 | 0.0267 | 0.1634 | 0.2688 | 0.3807 |
| 8 | 0.0253 | 0.1591 | 0.2618 | 0.3707 |
| 9 | 0.0236 | 0.1536 | 0.2527 | 0.3580 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 13 Summary Data: Average Daily CVaR

The worksheet shows daily CVaR for each of the nine 7 year rolling windows, calculated as the average of the worst 5% of returns calculated in Equity Worksheet 2.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Daily CVaR | | | | | | | | | | | | | |
| 1 | 0.0305 | 0.0261 | 0.0291 | 0.0316 | 0.0253 | 0.0410 | 0.0505 | 0.0296 | 0.0323 | 0.0243 | 0.0300 | 0.0252 | 0.0348 |
| 2 | 0.0316 | 0.0276 | 0.0296 | 0.0310 | 0.0260 | 0.0394 | 0.0462 | 0.0307 | 0.0335 | 0.0250 | 0.0304 | 0.0277 | 0.0397 |
| 3 | 0.0318 | 0.0304 | 0.0308 | 0.0320 | 0.0263 | 0.0426 | | 0.0316 | 0.0333 | 0.0271 | 0.0313 | 0.0289 | 0.0399 |
| 4 | 0.0345 | 0.0334 | 0.0344 | 0.0352 | 0.0286 | 0.0448 | | 0.0327 | 0.0338 | 0.0276 | 0.0324 | 0.0301 | 0.0424 |
| 5 | 0.0364 | 0.0341 | 0.0365 | 0.0365 | 0.0285 | 0.0448 | | 0.0328 | 0.0340 | 0.0316 | 0.0312 | 0.0300 | 0.0425 |
| 6 | 0.0368 | 0.0336 | 0.0367 | 0.0366 | 0.0282 | | | 0.0314 | 0.0325 | 0.0319 | 0.0335 | 0.0294 | 0.0413 |
| 7 | 0.0367 | 0.0343 | 0.0357 | 0.0374 | 0.0280 | | | 0.0299 | 0.0343 | 0.0320 | 0.0342 | 0.0307 | 0.0425 |
| 8 | 0.0364 | 0.0353 | 0.0360 | 0.0358 | 0.0277 | | | 0.0282 | 0.0361 | 0.0315 | 0.0349 | 0.0313 | 0.0441 |
| 9 | 0.0371 | 0.0353 | 0.0349 | 0.0360 | 0.0275 | | | 0.0269 | 0.0358 | 0.0323 | 0.0346 | 0.0319 | 0.0389 |

## Appendix 2 continued. Equity Model – Sample (Banks)

### Equity Worksheet 14 Summary Data: Weighted CVaR

CVaR for each entity, as obtained in the above worksheet, is multiplied by the weightings in Equity Worksheet 4, and then summed to obtain weighted portfolio CVaR.

| Weighted CVaR | *Total Portfolio* | *ADELAIDE BANK* | *AUS.AND NZ.BANKING GP.* | *BANK OF QLND.* | *BENDIGO BANK* | *COMMONWEALTH BK.OF AUS.* | *HOME BUILDING SOC.* | *MORTGAGE CHOICE* | *NATIONAL AUS.BANK* | *ROCK BUILDING SOCIETY* | *SAINT GEORGE BANK* | *SUNCORP-METWAY* | *WESTPAC BANKING* | *WIDE BAY AUSTRALIA* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.02681 | 0.00018 | 0.00537 | 0.00019 | 0.00023 | 0.00614 | 0.00004 | 0.00006 | 0.00710 | 0.00001 | 0.00158 | 0.00138 | 0.00449 | 0.00003 |
| 2 | 0.02804 | 0.00019 | 0.00530 | 0.00018 | 0.00020 | 0.00636 | 0.00002 | 0.00003 | 0.00753 | 0.00001 | 0.00168 | 0.00169 | 0.00481 | 0.00003 |
| 3 | 0.02932 | 0.00017 | 0.00591 | 0.00019 | 0.00024 | 0.00626 | 0.00002 | | 0.00801 | 0.00001 | 0.00179 | 0.00146 | 0.00522 | 0.00003 |
| 4 | 0.03117 | 0.00018 | 0.00598 | 0.00018 | 0.00023 | 0.00628 | 0.00002 | | 0.00997 | 0.00001 | 0.00178 | 0.00127 | 0.00523 | 0.00003 |
| 5 | 0.03157 | 0.00016 | 0.00637 | 0.00016 | 0.00022 | 0.00641 | 0.00001 | | 0.01044 | 0.00001 | 0.00180 | 0.00126 | 0.00469 | 0.00003 |
| 6 | 0.03090 | 0.00016 | 0.00608 | 0.00017 | 0.00021 | 0.00682 | | | 0.00946 | 0.00001 | 0.00167 | 0.00151 | 0.00480 | 0.00002 |
| 7 | 0.03062 | 0.00014 | 0.00587 | 0.00015 | 0.00019 | 0.00731 | | | 0.00900 | 0.00001 | 0.00139 | 0.00128 | 0.00526 | 0.00002 |
| 8 | 0.03016 | 0.00017 | 0.00538 | 0.00018 | 0.00024 | 0.00753 | | | 0.00916 | 0.00001 | 0.00146 | 0.00140 | 0.00460 | 0.00003 |
| 9 | 0.02992 | 0.00021 | 0.00536 | 0.00020 | 0.00022 | 0.00666 | | | 0.00878 | 0.00001 | 0.00176 | 0.00137 | 0.00531 | 0.00002 |

**Appendix 2 continued. Equity Model – Sample (Banks)**

Equity Worksheet 15 Summary Data: Parametric / Nonparametric Comparison

Parametric Values are based on tail 5% of the normal distribution using equation 2.33. Nonparametric values are based on the weighted average portfolio CVaR as per Equity Worksheet 14.

| Year | Parametric Annual CVaR | Parametric Daily CVaR | Nonparametric Daily CVaR |
|---|---|---|---|
| 1 | 0.37981 | 0.02402 | 0.0268 |
| 2 | 0.40197 | 0.02542 | 0.0280 |
| 3 | 0.42890 | 0.02713 | 0.0293 |
| 4 | 0.45406 | 0.02872 | 0.0312 |
| 5 | 0.45712 | 0.02891 | 0.0316 |
| 6 | 0.44560 | 0.02818 | 0.0309 |
| 7 | 0.44186 | 0.02795 | 0.0306 |
| 8 | 0.43277 | 0.02737 | 0.0302 |
| 9 | 0.42428 | 0.02683 | 0.0299 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 16 Summary Data: Standard Deviation – One Year

Standard deviation is calculated in the same manner as Equity Worksheet 3, but using 1 year data tranches instead of 7 year rolling windows

| | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard Deviation - one year | | | | | | | | | | | | | | |
| 1 | | 0.2022 | 0.1500 | 0.2344 | 0.2542 | 0.1334 | 0.2798 | 0.3849 | 0.1495 | 0.1967 | 0.1452 | 0.1752 | 0.1468 | 0.2298 |
| 2 | | 0.1870 | 0.1398 | 0.1821 | 0.1660 | 0.1395 | 0.2122 | 0.3129 | 0.1145 | 0.1972 | 0.1206 | 0.1790 | 0.1415 | 0.1795 |
| 3 | | 0.1680 | 0.1379 | 0.2019 | 0.2031 | 0.1290 | 0.2704 | | 0.1549 | 0.1558 | 0.1657 | 0.1487 | 0.1463 | 0.1731 |
| 4 | | 0.1889 | 0.1969 | 0.1772 | 0.2019 | 0.1843 | 0.2891 | | 0.1857 | 0.2007 | 0.1518 | 0.2375 | 0.2138 | 0.1957 |
| 5 | | 0.2191 | 0.2198 | 0.2068 | 0.2152 | 0.2002 | 0.3100 | | 0.2296 | 0.2525 | 0.1848 | 0.2444 | 0.1923 | 0.2421 |
| 6 | | 0.2274 | 0.2134 | 0.2440 | 0.2011 | 0.2022 | | | 0.2547 | 0.2348 | 0.1912 | 0.2335 | 0.1832 | 0.2264 |
| 7 | | 0.2634 | 0.2133 | 0.1326 | 0.2518 | 0.2064 | | | 0.2510 | 0.2065 | 0.1925 | 0.1685 | 0.2115 | 0.2587 |
| 8 | | 0.2363 | 0.2529 | 0.2272 | 0.2322 | 0.2091 | | | 0.2221 | 0.2370 | 0.1760 | 0.2157 | 0.2516 | 0.3879 |
| 9 | | 0.2020 | 0.2875 | 0.2280 | 0.2606 | 0.1996 | | | 0.2278 | 0.1812 | 0.2129 | 0.2138 | 0.2363 | 0.1743 |

## Appendix 2 continued. Equity Model – Sample (Banks)

Equity Worksheet 17 Weighted Standard Deviation – One Year

Weightings in Equity Worksheet 4 are applied to the one year standard deviations in Equity Worksheet 16.

| | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weighted Standard Deviation - one year | | | | | | | | | | | | | | |
| 1 | 0.1483 | 0.0012 | 0.0308 | 0.0015 | 0.0019 | 0.0323 | 0.0003 | 0.0005 | 0.0359 | 0.0001 | 0.0095 | 0.0080 | 0.0261 | 0.0002 |
| 2 | 0.1356 | 0.0011 | 0.0268 | 0.0011 | 0.0011 | 0.0341 | 0.0001 | 0.0002 | 0.0281 | 0.0001 | 0.0081 | 0.0099 | 0.0246 | 0.0001 |
| 3 | 0.1451 | 0.0009 | 0.0268 | 0.0012 | 0.0016 | 0.0307 | 0.0001 | | 0.0392 | 0.0001 | 0.0110 | 0.0069 | 0.0265 | 0.0001 |
| 4 | 0.1923 | 0.0010 | 0.0353 | 0.0009 | 0.0013 | 0.0405 | 0.0001 | | 0.0566 | 0.0001 | 0.0098 | 0.0093 | 0.0371 | 0.0002 |
| 5 | 0.2131 | 0.0009 | 0.0411 | 0.0009 | 0.0013 | 0.0451 | 0.0001 | | 0.0730 | 0.0001 | 0.0106 | 0.0098 | 0.0300 | 0.0002 |
| 6 | 0.2181 | 0.0010 | 0.0386 | 0.0011 | 0.0011 | 0.0489 | | | 0.0768 | 0.0001 | 0.0100 | 0.0105 | 0.0299 | 0.0001 |
| 7 | 0.2200 | 0.0010 | 0.0364 | 0.0006 | 0.0013 | 0.0539 | | | 0.0757 | 0.0001 | 0.0084 | 0.0063 | 0.0363 | 0.0001 |
| 8 | 0.2255 | 0.0011 | 0.0385 | 0.0011 | 0.0016 | 0.0569 | | | 0.0722 | 0.0001 | 0.0082 | 0.0087 | 0.0370 | 0.0002 |
| 9 | 0.2301 | 0.0012 | 0.0437 | 0.0013 | 0.0016 | 0.0483 | | | 0.0744 | 0.0001 | 0.0116 | 0.0084 | 0.0394 | 0.0001 |

**Appendix 2 continued. Equity Model – Sample (Banks)**

Equity Worksheet 18 One Year Summary

A summary of portfolio values for each of the nine years is provided, based on 12 month data frames.

| Year | Weighted Standard Deviation | Undiversified VaR |
|---|---|---|
| 1 | 0.1483 | 0.2439 |
| 2 | 0.1356 | 0.2231 |
| 3 | 0.1451 | 0.2387 |
| 4 | 0.1923 | 0.3163 |
| 5 | 0.2131 | 0.3506 |
| 6 | 0.2181 | 0.3588 |
| 7 | 0.2200 | 0.3620 |
| 8 | 0.2255 | 0.3709 |
| 9 | 0.2301 | 0.3785 |

# Appendix 3. Structural Model

### Worksheets

## Appendix 3 continued. Structural Model – Sample (All Industries)

Structural Worksheet 1 Data ($000)

ASX codes, market value, total liabilities, current liabilities, and long term liabilities are all obtained from Datastream. Consistent with KMV methodology described in 2.5.4.1, asset value of firm is the market value plus total liabilities, and debt is current liabilities plus ½ long term liabilities. This is only a very small illustrative sample of total companies included in the study from the All Ords index.

| Company Name | ASX Code | Market Value | Total Liabilities | Current Liabilities | Long Term Liabilities | Asset Value of Firm | Debt |
|---|---|---|---|---|---|---|---|
| AAV | AVV | 92250 | 50497 | 34064 | 16433 | 142747 | 42280.5 |
| ABACUS PROPERTY GROUP | ABP | 803290 | 189101 | 46187 | 142914 | 992391 | 117644 |
| ABB GRAIN | ABB | 975830 | 320139 | 199279 | 120860 | 1295969 | 259709 |
| ABC LEARNING CENTRES | ABS | 2634080 | 317076 | 65810 | 251266 | 2951156 | 191443 |
| ABERDEEN LEADERS | ALR | 96760 | 33435 | 8435 | 25000 | 130195 | 20935 |
| ACRUX | ACR | 85950 | 1612 | 1581 | 31 | 87562 | 1596.5 |
| ADEL.BRIGHTON | ADB | 1366230 | 469079 | 381721 | 87358 | 1835309 | 425400 |
| ADELAIDE BANK | ABC | 1422110 | 12627050 | 12315045 | 312005 | 14049160 | 12471048 |
| ADSTEAM & MARINE | ADZ | 706490 | 402509 | 121358 | 281151 | 1108999 | 261933.5 |
| ADTRANS GROUP | ADG | 64130 | 112110 | 102135 | 9975 | 176240 | 107122.5 |
| AGINCOURT RESOURCES | AGC | 134800 | 22007 | 10264 | 11743 | 156807 | 16135.5 |
| AINSWORTH GAME TECH. | AGI | 72740 | 80201 | 27356 | 52845 | 152941 | 53778.5 |
| ALCHEMIA | ACL | 147140 | 3764 | 2967 | 797 | 150904 | 3365.5 |
| ALE PROPERTY GROUP | LEP | 240620 | 494028 | 14028 | 480000 | 734648 | 254028 |
| ALESCO | ALS | 636460 | 234239 | 134274 | 99965 | 870699 | 184256.5 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 2 Standard Deviation

The worksheet shows standard deviation of returns on asset values, noting that that this is after applying the iterative procedure to asset values described in Section 3.4.2.

| Stdev | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0210 | 0.0277 | 0.0261 | 0.0266 | 0.0283 | 0.0490 | 0.3303 | 0.0265 | 0.0312 | 0.0294 | 0.0410 | 0.0263 | 0.0427 |
| 2 | 0.0221 | 0.0305 | 0.0261 | 0.0263 | 0.0300 | 0.0494 | 0.2951 | 0.0280 | 0.0326 | 0.0302 | 0.0420 | 0.0293 | 0.0519 |
| 3 | 0.0224 | 0.0349 | 0.0269 | 0.0273 | 0.0313 | 0.0531 | | 0.0298 | 0.0326 | 0.0322 | 0.0433 | 0.0317 | 0.0521 |
| 4 | 0.0239 | 0.0376 | 0.0292 | 0.0297 | 0.0328 | 0.0540 | | 0.0303 | 0.0341 | 0.0331 | 0.0446 | 0.0329 | 0.0543 |
| 5 | 0.0247 | 0.0375 | 0.0303 | 0.0306 | 0.0326 | 0.0636 | | 0.0299 | 0.0342 | 0.0369 | 0.0425 | 0.0329 | 0.0548 |
| 6 | 0.0247 | 0.0365 | 0.0302 | 0.0308 | 0.0314 | | | 0.0289 | 0.0332 | 0.0370 | 0.0432 | 0.0320 | 0.0551 |
| 7 | 0.0254 | 0.0382 | 0.0297 | 0.0319 | 0.0304 | | | 0.0270 | 0.0358 | 0.0381 | 0.0449 | 0.0338 | 0.0572 |
| 8 | 0.0250 | 0.0387 | 0.0304 | 0.0304 | 0.0296 | | | 0.0256 | 0.0357 | 0.0375 | 0.0459 | 0.0340 | 0.0572 |
| 9 | 0.0245 | 0.0388 | 0.0287 | 0.0305 | 0.0284 | | | 0.0238 | 0.0352 | 0.0376 | 0.0450 | 0.0343 | 0.0471 |

**Appendix 3 continued. Structural Model – Sample (Banks)**

Structural Worksheet 3 Weightings

Each company in the industry is weighted by asset values, for each of the nine 7 year rolling windows.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weightings | | | | | | | | | | | | | |
| 1 | 0.0088 | 0.2019 | 0.0074 | 0.0089 | 0.2263 | 0.0008 | 0.0002 | 0.2768 | 0.0004 | 0.0552 | 0.0342 | 0.1785 | 0.0006 |
| 2 | 0.0089 | 0.2000 | 0.0074 | 0.0088 | 0.2264 | 0.0007 | 0.0001 | 0.2783 | 0.0004 | 0.0553 | 0.0353 | 0.1779 | 0.0006 |
| 3 | 0.0090 | 0.1896 | 0.0071 | 0.0080 | 0.2276 | 0.0004 | | 0.2846 | 0.0004 | 0.0567 | 0.0402 | 0.1760 | 0.0005 |
| 4 | 0.0077 | 0.1883 | 0.0070 | 0.0091 | 0.2189 | 0.0004 | | 0.3011 | 0.0004 | 0.0557 | 0.0336 | 0.1773 | 0.0006 |
| 5 | 0.0073 | 0.1760 | 0.0060 | 0.0078 | 0.2036 | 0.0003 | | 0.3464 | 0.0003 | 0.0527 | 0.0290 | 0.1702 | 0.0005 |
| 6 | 0.0063 | 0.1793 | 0.0051 | 0.0072 | 0.2093 | | | 0.3590 | 0.0003 | 0.0470 | 0.0305 | 0.1553 | 0.0005 |
| 7 | 0.0063 | 0.1761 | 0.0052 | 0.0066 | 0.2255 | | | 0.3419 | 0.0003 | 0.0416 | 0.0323 | 0.1637 | 0.0004 |
| 8 | 0.0057 | 0.1621 | 0.0050 | 0.0062 | 0.2423 | | | 0.3461 | 0.0003 | 0.0365 | 0.0278 | 0.1675 | 0.0004 |
| 9 | 0.0070 | 0.1490 | 0.0058 | 0.0079 | 0.2436 | | | 0.3680 | 0.0004 | 0.0398 | 0.0292 | 0.1489 | 0.0004 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 4 Weighted Standard Deviation

The standard deviation for each entity, as obtained in Structural Worksheet 2, is multiplied by the weightings in Structural Worksheet 3.

| Weighted stdev | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0278 | 0.0002 | 0.0056 | 0.0002 | 0.0002 | 0.0064 | 0.0000 | 0.0001 | 0.0073 | 0.0000 | 0.0016 | 0.0014 | 0.0047 | 0.0000 |
| 2 | 0.0298 | 0.0002 | 0.0061 | 0.0002 | 0.0002 | 0.0068 | 0.0000 | 0.0000 | 0.0078 | 0.0000 | 0.0017 | 0.0015 | 0.0052 | 0.0000 |
| 3 | 0.0320 | 0.0002 | 0.0066 | 0.0002 | 0.0002 | 0.0071 | 0.0000 | | 0.0085 | 0.0000 | 0.0018 | 0.0017 | 0.0056 | 0.0000 |
| 4 | 0.0333 | 0.0002 | 0.0071 | 0.0002 | 0.0003 | 0.0072 | 0.0000 | | 0.0091 | 0.0000 | 0.0018 | 0.0015 | 0.0058 | 0.0000 |
| 5 | 0.0330 | 0.0002 | 0.0066 | 0.0002 | 0.0002 | 0.0066 | 0.0000 | | 0.0103 | 0.0000 | 0.0019 | 0.0012 | 0.0056 | 0.0000 |
| 6 | 0.0321 | 0.0002 | 0.0066 | 0.0002 | 0.0002 | 0.0066 | | | 0.0104 | 0.0000 | 0.0017 | 0.0013 | 0.0050 | 0.0000 |
| 7 | 0.0319 | 0.0002 | 0.0067 | 0.0002 | 0.0002 | 0.0068 | | | 0.0092 | 0.0000 | 0.0016 | 0.0015 | 0.0055 | 0.0000 |
| 8 | 0.0312 | 0.0001 | 0.0063 | 0.0002 | 0.0002 | 0.0072 | | | 0.0088 | 0.0000 | 0.0014 | 0.0013 | 0.0057 | 0.0000 |
| 9 | 0.0300 | 0.0002 | 0.0058 | 0.0002 | 0.0002 | 0.0069 | | | 0.0088 | 0.0000 | 0.0015 | 0.0013 | 0.0051 | 0.0000 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 5 Revised Asset Values ($000)

Asset values are calculated using the iterative procedure described Section 3.4.2.

| | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Revised asset value | | | | | | | | | | | | | | |
| 1 | 1522163 | 13397 | 307297 | 11315 | 13590 | 344488 | 1184 | 315 | 421283 | 554 | 84008 | 52124 | 271632 | 976 |
| 2 | 1491807 | 13253 | 298302 | 11035 | 13173 | 337674 | 1062 | 168 | 415122 | 541 | 82470 | 52726 | 265365 | 914 |
| 3 | 1103345 | 8513 | 209506 | 7816 | 10228 | 244794 | 409 | | 324950 | 404 | 61680 | 38218 | 196199 | 630 |
| 4 | 1103463 | 8532 | 207770 | 7677 | 10086 | 241559 | 399 | | 332246 | 402 | 61427 | 37111 | 195623 | 632 |
| 5 | 1158006 | 8444 | 203784 | 6962 | 9018 | 235770 | 336 | | 401086 | 393 | 60969 | 33574 | 197043 | 627 |
| 6 | 1135200 | 7201 | 203567 | 5791 | 8196 | 237632 | | | 407531 | 388 | 53408 | 34656 | 176267 | 561 |
| 7 | 977457 | 6179 | 172096 | 5059 | 6462 | 220428 | | | 334235 | 292 | 40679 | 31588 | 160056 | 384 |
| 8 | 867375 | 4978 | 140595 | 4363 | 5412 | 210201 | | | 300188 | 277 | 31687 | 24087 | 145279 | 308 |
| 9 | 762852 | 5373 | 113702 | 4448 | 6003 | 185822 | | | 280737 | 269 | 30330 | 22238 | 113601 | 331 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 6 Asset Returns

Asset returns are recalculated using the iterative procedure described Section 3.4.2.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asset Return | | | | | | | | | | | | | |
| 1 | 0.0124 | 0.0204 | 0.0169 | 0.0128 | 0.0131 | 0.0652 | 0.4324 | 0.0064 | 0.0147 | 0.0248 | 0.0218 | 0.0180 | 0.0281 |
| 2 | 0.0099 | 0.0155 | 0.0125 | 0.0145 | 0.0139 | 0.0530 | 0.2339 | 0.0050 | 0.0109 | 0.0217 | 0.0276 | 0.0127 | 0.0209 |
| 3 | 0.0068 | 0.0137 | 0.0122 | 0.0172 | 0.0144 | 0.0456 | | 0.0051 | 0.0086 | 0.0224 | 0.0234 | 0.0138 | 0.0215 |
| 4 | 0.0086 | 0.0167 | 0.0077 | 0.0116 | 0.0198 | 0.0582 | | 0.0140 | 0.0034 | 0.0214 | 0.0263 | 0.0169 | 0.0245 |
| 5 | 0.0088 | 0.0230 | 0.0084 | 0.0116 | 0.0233 | 0.0000 | | 0.0186 | 0.0063 | 0.0234 | 0.0350 | 0.0200 | 0.0280 |
| 6 | 0.0110 | 0.0265 | 0.0078 | 0.0135 | 0.0271 | | | 0.0175 | 0.0040 | 0.0249 | 0.0411 | 0.0225 | 0.0200 |
| 7 | 0.0002 | 0.0193 | 0.0003 | 0.0034 | 0.0229 | | | 0.0125 | -0.0029 | 0.0080 | 0.0248 | 0.0202 | 0.0040 |
| 8 | 0.0024 | 0.0230 | -0.0003 | 0.0082 | 0.0292 | | | 0.0187 | 0.0113 | 0.0130 | 0.0340 | 0.0228 | 0.0098 |
| 9 | 0.0044 | 0.0127 | 0.0033 | 0.0054 | 0.0193 | | | 0.0168 | 0.0163 | 0.0127 | 0.0315 | 0.0137 | 0.0072 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 7 Debt ($m)

Debt values calculated in Structural Worksheet 1 are held constant for the nine rolling windows for reasons discussed in Section 3.3.2.

| Debt ($m) | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1228391 | 12471 | 247219 | 9848 | 12347 | 279029 | 964 | 15 | 336257 | 489 | 67053 | 38852 | 223038 | 809 |
| 2 | 1228391 | 12471 | 247219 | 9848 | 12347 | 279029 | 964 | 15 | 336257 | 489 | 67053 | 38852 | 223038 | 809 |
| 3 | 1228376 | 12471 | 247219 | 9848 | 12347 | 279029 | 964 | | 336257 | 489 | 67053 | 38852 | 223038 | 809 |
| 4 | 1228376 | 12471 | 247219 | 9848 | 12347 | 279029 | 964 | | 336257 | 489 | 67053 | 38852 | 223038 | 809 |
| 5 | 1228376 | 12471 | 247219 | 9848 | 12347 | 279029 | 964 | | 336257 | 489 | 67053 | 38852 | 223038 | 809 |
| 6 | 1227412 | 12471 | 247219 | 9848 | 12347 | 279029 | | | 336257 | 489 | 67053 | 38852 | 223038 | 809 |
| 7 | 1227412 | 12471 | 247219 | 9848 | 12347 | 279029 | | | 336257 | 489 | 67053 | 38852 | 223038 | 809 |
| 8 | 1227412 | 12471 | 247219 | 9848 | 12347 | 279029 | | | 336257 | 489 | 67053 | 38852 | 223038 | 809 |
| 9 | 1227412 | 12471 | 247219 | 9848 | 12347 | 279029 | | | 336257 | 489 | 67053 | 38852 | 223038 | 809 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 8 Distance to Default

Distance to default is calculated using the formula $DD = \dfrac{\ln(V/F) + (\mu - 0.5_v^2)T}{\sigma_V \sqrt{T}}$ as described in Section 2.5.4.1.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Distance to default | | | | | | | | | | | | | |
| 1 | 3.9986 | 8.5660 | 5.9465 | 4.0798 | 7.9092 | 5.4896 | 10.3946 | 8.7502 | 4.4536 | 8.5003 | 7.6893 | 8.1589 | 5.0503 |
| 2 | 3.6851 | 7.6221 | 5.7839 | 4.1817 | 7.4727 | 5.2008 | 11.0014 | 8.2086 | 4.1514 | 8.1687 | 7.6289 | 7.1345 | 4.0088 |
| 3 | 3.4913 | 6.6131 | 5.5975 | 4.1349 | 7.1783 | 4.6960 | | 7.7330 | 4.0721 | 7.6746 | 7.3130 | 6.6480 | 4.0075 |
| 4 | 3.3538 | 6.2164 | 5.0093 | 3.6068 | 7.0099 | 4.8487 | | 7.8824 | 3.7429 | 7.4329 | 7.1628 | 6.4836 | 3.8976 |
| 5 | 3.2512 | 6.3948 | 4.8501 | 3.4940 | 7.1689 | 3.1939 | | 8.1599 | 3.8100 | 6.7297 | 7.7117 | 6.5938 | 3.9257 |
| 6 | 3.3381 | 6.6592 | 4.8386 | 3.5344 | 7.5705 | | | 8.3783 | 3.8640 | 6.7389 | 7.7256 | 6.8516 | 3.7585 |
| 7 | 2.8139 | 6.1786 | 4.6746 | 3.0971 | 7.6792 | | | 8.7939 | 3.3824 | 6.1112 | 7.0739 | 6.4087 | 3.3364 |
| 8 | 2.9565 | 6.1938 | 4.5386 | 3.4123 | 8.0862 | | | 9.5433 | 3.7902 | 6.3420 | 7.1137 | 6.4442 | 3.4382 |
| 9 | 3.0969 | 5.9112 | 4.9390 | 3.3059 | 8.0782 | | | 10.1645 | 3.9904 | 6.3201 | 7.2071 | 6.1264 | 4.1341 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 9 Calibrated PD

CPD is calculated as $N(-DD)$ as described in Section 2.5.4.1 and calibrated to EDF values as described in Section 3.4.2.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Calibrated PD | | | | | | | | | | | | | |
| 1 | 0.0372 | 0.0037 | 0.0151 | 0.0359 | 0.0054 | 0.0189 | 0.0012 | 0.0033 | 0.0305 | 0.0038 | 0.0061 | 0.0047 | 0.0233 |
| 2 | 0.0425 | 0.0063 | 0.0164 | 0.0344 | 0.0068 | 0.0217 | 0.0008 | 0.0045 | 0.0348 | 0.0046 | 0.0063 | 0.0082 | 0.0371 |
| 3 | 0.0461 | 0.0108 | 0.0180 | 0.0351 | 0.0080 | 0.0274 | | 0.0059 | 0.0361 | 0.0061 | 0.0075 | 0.0106 | 0.0371 |
| 4 | 0.0487 | 0.0132 | 0.0237 | 0.0439 | 0.0088 | 0.0255 | | 0.0054 | 0.0415 | 0.0070 | 0.0081 | 0.0116 | 0.0389 |
| 5 | 0.0508 | 0.0121 | 0.0255 | 0.0460 | 0.0081 | 0.0520 | | 0.0047 | 0.0403 | 0.0102 | 0.0060 | 0.0109 | 0.0384 |
| 6 | 0.0490 | 0.0106 | 0.0257 | 0.0452 | 0.0065 | | | 0.0041 | 0.0394 | 0.0101 | 0.0059 | 0.0095 | 0.0412 |
| 7 | 0.0604 | 0.0135 | 0.0276 | 0.0540 | 0.0061 | | | 0.0032 | 0.0482 | 0.0140 | 0.0085 | 0.0120 | 0.0491 |
| 8 | 0.0571 | 0.0134 | 0.0294 | 0.0476 | 0.0049 | | | 0.0020 | 0.0407 | 0.0124 | 0.0083 | 0.0118 | 0.0471 |
| 9 | 0.0540 | 0.0154 | 0.0245 | 0.0497 | 0.0049 | | | 0.0014 | 0.0374 | 0.0126 | 0.0079 | 0.0138 | 0.0351 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 10 Weighted DD

The DD for each entity, as obtained in Structural Worksheet 8., is multiplied by the weightings in Structural Worksheet 3.

| | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weighted DD | | | | | | | | | | | | | | |
| 1 | 8.2566 | 0.0352 | 1.7293 | 0.0442 | 0.0364 | 1.7900 | 0.0043 | 0.0021 | 2.4218 | 0.0016 | 0.4691 | 0.2633 | 1.4560 | 0.0032 |
| 2 | 7.6114 | 0.0327 | 1.5241 | 0.0428 | 0.0369 | 1.6915 | 0.0037 | 0.0012 | 2.2842 | 0.0015 | 0.4516 | 0.2696 | 1.2691 | 0.0025 |
| 3 | 7.0968 | 0.0313 | 1.2536 | 0.0396 | 0.0330 | 1.6334 | 0.0021 | | 2.2008 | 0.0015 | 0.4353 | 0.2942 | 1.1700 | 0.0021 |
| 4 | 6.9816 | 0.0259 | 1.1705 | 0.0348 | 0.0330 | 1.5346 | 0.0018 | | 2.3733 | 0.0014 | 0.4138 | 0.2409 | 1.1494 | 0.0022 |
| 5 | 7.1955 | 0.0237 | 1.1254 | 0.0292 | 0.0272 | 1.4596 | 0.0009 | | 2.8262 | 0.0013 | 0.3543 | 0.2236 | 1.1220 | 0.0021 |
| 6 | 7.4780 | 0.0212 | 1.1941 | 0.0247 | 0.0255 | 1.5847 | | | 3.0078 | 0.0013 | 0.3170 | 0.2359 | 1.0639 | 0.0019 |
| 7 | 7.4237 | 0.0178 | 1.0878 | 0.0242 | 0.0205 | 1.7318 | | | 3.0070 | 0.0010 | 0.2543 | 0.2286 | 1.0494 | 0.0013 |
| 8 | 7.8385 | 0.0170 | 1.0040 | 0.0228 | 0.0213 | 1.9596 | | | 3.3028 | 0.0012 | 0.2317 | 0.1976 | 1.0794 | 0.0012 |
| 9 | 8.0430 | 0.0218 | 0.8811 | 0.0288 | 0.0260 | 1.9678 | | | 3.7406 | 0.0014 | 0.2513 | 0.2101 | 0.9123 | 0.0018 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 11 Extreme Returns

Extreme returns are shown for each of the nine 7 year rolling windows, calculated as the average of the worst 5% of asset returns as per Section 3.5.2.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Extreme returns | | | | | | | | | | | | | |
| 1 | 0.0036 | 0.0046 | 0.0046 | 0.0047 | 0.0049 | 0.0092 | 0.0563 | 0.0046 | 0.0059 | 0.0050 | 0.0073 | 0.0043 | 0.0084 |
| 2 | 0.0039 | 0.0050 | 0.0047 | 0.0046 | 0.0050 | 0.0091 | 0.0487 | 0.0048 | 0.0062 | 0.0052 | 0.0073 | 0.0049 | 0.0095 |
| 3 | 0.0039 | 0.0057 | 0.0049 | 0.0047 | 0.0051 | 0.0096 | | 0.0050 | 0.0062 | 0.0055 | 0.0075 | 0.0052 | 0.0096 |
| 4 | 0.0042 | 0.0062 | 0.0051 | 0.0054 | 0.0053 | 0.0100 | | 0.0050 | 0.0063 | 0.0057 | 0.0077 | 0.0053 | 0.0103 |
| 5 | 0.0044 | 0.0062 | 0.0054 | 0.0056 | 0.0054 | 0.0113 | | 0.0050 | 0.0063 | 0.0065 | 0.0076 | 0.0053 | 0.0103 |
| 6 | 0.0044 | 0.0061 | 0.0054 | 0.0056 | 0.0053 | | | 0.0049 | 0.0062 | 0.0066 | 0.0079 | 0.0052 | 0.0104 |
| 7 | 0.0045 | 0.0065 | 0.0053 | 0.0058 | 0.0052 | | | 0.0046 | 0.0068 | 0.0068 | 0.0082 | 0.0055 | 0.0110 |
| 8 | 0.0045 | 0.0066 | 0.0054 | 0.0055 | 0.0051 | | | 0.0043 | 0.0069 | 0.0067 | 0.0083 | 0.0056 | 0.0108 |
| 9 | 0.0045 | 0.0066 | 0.0051 | 0.0056 | 0.0051 | | | 0.0041 | 0.0069 | 0.0068 | 0.0082 | 0.0058 | 0.0097 |

**Appendix 3 continued. Structural Model – Sample (Banks)**

Structural Worksheet 12 Weighted Extreme Returns

Extreme returns shown in Structural Worksheet 11 are weighted as per Structural Worksheet 3.

| | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weighted extreme returns | | | | | | | | | | | | | | |
| 1 | 0.00472 | 0.00003 | 0.00093 | 0.00003 | 0.00004 | 0.00110 | 0.00001 | 0.00001 | 0.00126 | 0.00000 | 0.00028 | 0.00025 | 0.00076 | 0.00001 |
| 2 | 0.00502 | 0.00003 | 0.00101 | 0.00003 | 0.00004 | 0.00114 | 0.00001 | 0.00001 | 0.00134 | 0.00000 | 0.00029 | 0.00026 | 0.00087 | 0.00001 |
| 3 | 0.00531 | 0.00004 | 0.00109 | 0.00003 | 0.00004 | 0.00116 | 0.00000 | | 0.00141 | 0.00000 | 0.00031 | 0.00030 | 0.00091 | 0.00001 |
| 4 | 0.00550 | 0.00003 | 0.00117 | 0.00004 | 0.00005 | 0.00117 | 0.00000 | | 0.00151 | 0.00000 | 0.00032 | 0.00026 | 0.00094 | 0.00001 |
| 5 | 0.00549 | 0.00003 | 0.00109 | 0.00003 | 0.00004 | 0.00110 | 0.00000 | | 0.00172 | 0.00000 | 0.00034 | 0.00022 | 0.00090 | 0.00001 |
| 6 | 0.00543 | 0.00003 | 0.00109 | 0.00003 | 0.00004 | 0.00111 | | | 0.00176 | 0.00000 | 0.00031 | 0.00024 | 0.00081 | 0.00001 |
| 7 | 0.00544 | 0.00003 | 0.00114 | 0.00003 | 0.00004 | 0.00117 | | | 0.00157 | 0.00000 | 0.00028 | 0.00027 | 0.00090 | 0.00000 |
| 8 | 0.00533 | 0.00003 | 0.00108 | 0.00003 | 0.00003 | 0.00124 | | | 0.00150 | 0.00000 | 0.00024 | 0.00023 | 0.00094 | 0.00000 |
| 9 | 0.00521 | 0.00003 | 0.00099 | 0.00003 | 0.00004 | 0.00124 | | | 0.00149 | 0.00000 | 0.00027 | 0.00024 | 0.00086 | 0.00000 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 13 CStdev (nonparametric)

To calculate the conditional standard deviation (CStdev) we multiply the standard deviation for all returns by the percentage difference between all returns and the extreme 5% of returns, as discussed in Section 3.5.2.

| Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cstdev (nonparametric) | | | | | | | | | | | | | |
| 1 | 0.0808 | 0.0982 | 0.1016 | 0.1049 | 0.1049 | 0.2344 | 1.3733 | 0.1036 | 0.1514 | 0.1080 | 0.1648 | 0.0893 | 0.2390 |
| 2 | 0.0873 | 0.1046 | 0.1044 | 0.0998 | 0.1051 | 0.2275 | 1.2508 | 0.1058 | 0.1592 | 0.1113 | 0.1622 | 0.1006 | 0.3216 |
| 3 | 0.0877 | 0.1220 | 0.1114 | 0.1033 | 0.1069 | 0.2390 | | 0.1090 | 0.1607 | 0.1201 | 0.1687 | 0.1080 | 0.3275 |
| 4 | 0.0959 | 0.1323 | 0.1286 | 0.1250 | 0.1122 | 0.2501 | | 0.1089 | 0.1593 | 0.1224 | 0.1730 | 0.1117 | 0.3507 |
| 5 | 0.1003 | 0.1324 | 0.1410 | 0.1308 | 0.1144 | 0.2738 | | 0.1092 | 0.1597 | 0.1441 | 0.1751 | 0.1122 | 0.3457 |
| 6 | 0.1017 | 0.1313 | 0.1422 | 0.1317 | 0.1145 | | | 0.1084 | 0.1588 | 0.1478 | 0.1838 | 0.1111 | 0.3601 |
| 7 | 0.1049 | 0.1407 | 0.1428 | 0.1366 | 0.1124 | | | 0.0987 | 0.1848 | 0.1528 | 0.1906 | 0.1173 | 0.3898 |
| 8 | 0.1056 | 0.1444 | 0.1453 | 0.1312 | 0.1115 | | | 0.0933 | 0.1915 | 0.1512 | 0.1949 | 0.1208 | 0.3958 |
| 9 | 0.1066 | 0.1456 | 0.1431 | 0.1366 | 0.1133 | | | 0.0878 | 0.1915 | 0.1547 | 0.1950 | 0.1259 | 0.3081 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 14 CDD (nonparametric)

CDD is calculated by substituting CStdev (as calculated in Structural Worksheet 13) for Stdev into the DD formula, as discussed in Section 3.5.2.

| CDD (nonparametric) | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0375 | 2.4192 | 1.5302 | 1.0341 | 2.1301 | 1.1485 | 2.5001 | 2.2345 | 0.9172 | 2.3125 | 1.9106 | 2.4039 | 0.9023 |
| 2 | 0.9311 | 2.2242 | 1.4461 | 1.1025 | 2.1339 | 1.1298 | 2.5951 | 2.1742 | 0.8486 | 2.2165 | 1.9758 | 2.0809 | 0.6469 |
| 3 | 0.8917 | 1.8903 | 1.3526 | 1.0919 | 2.1007 | 1.0437 | | 2.1118 | 0.8265 | 2.0590 | 1.8751 | 1.9477 | 0.6371 |
| 4 | 0.8342 | 1.7650 | 1.1365 | 0.8572 | 2.0504 | 1.0475 | | 2.1948 | 0.8004 | 2.0131 | 1.8454 | 1.9100 | 0.6032 |
| 5 | 0.7992 | 1.8119 | 1.0415 | 0.8182 | 2.0402 | 0.7421 | | 2.2310 | 0.8167 | 1.7220 | 1.8731 | 1.9303 | 0.6219 |
| 6 | 0.8094 | 1.8532 | 1.0286 | 0.8272 | 2.0737 | | | 2.2371 | 0.8071 | 1.6889 | 1.8173 | 1.9718 | 0.5746 |
| 7 | 0.6824 | 1.6778 | 0.9718 | 0.7235 | 2.0756 | | | 2.4063 | 0.6556 | 1.5230 | 1.6665 | 1.8477 | 0.4898 |
| 8 | 0.6989 | 1.6600 | 0.9508 | 0.7905 | 2.1487 | | | 2.6142 | 0.7070 | 1.5723 | 1.6765 | 1.8160 | 0.4969 |
| 9 | 0.7103 | 1.5765 | 0.9907 | 0.7388 | 2.0263 | | | 2.7547 | 0.7330 | 1.5341 | 1.6632 | 1.6691 | 0.6316 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 15 Calibrated CPD

CPD is calculated by substituting CDD (per Structural Worksheet 14) for DD into the PD formula and calibrated to EDF values as discussed in Sections 3.4.2 and 3.5.2.

| Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Calibrated CPD | | | | | | | | | | | | | |
| 1 | 0.1145 | 0.0703 | 0.0969 | 0.1147 | 0.0782 | 0.1104 | 0.0681 | 0.0753 | 0.1192 | 0.0731 | 0.0847 | 0.0707 | 0.1198 |
| 2 | 0.1186 | 0.0755 | 0.0998 | 0.1121 | 0.0781 | 0.1111 | 0.0657 | 0.0770 | 0.1219 | 0.0758 | 0.0827 | 0.0796 | 0.1301 |
| 3 | 0.1202 | 0.0853 | 0.1030 | 0.1125 | 0.0791 | 0.1143 | | 0.0787 | 0.1228 | 0.0803 | 0.0858 | 0.0836 | 0.1305 |
| 4 | 0.1224 | 0.0892 | 0.1108 | 0.1215 | 0.0805 | 0.1142 | | 0.0764 | 0.1238 | 0.0816 | 0.0867 | 0.0847 | 0.1319 |
| 5 | 0.1238 | 0.0878 | 0.1144 | 0.1231 | 0.0808 | 0.1262 | | 0.0754 | 0.1231 | 0.0906 | 0.0859 | 0.0841 | 0.1311 |
| 6 | 0.1234 | 0.0865 | 0.1149 | 0.1227 | 0.0798 | | | 0.0752 | 0.1235 | 0.0917 | 0.0876 | 0.0829 | 0.1331 |
| 7 | 0.1286 | 0.0920 | 0.1171 | 0.1269 | 0.0798 | | | 0.0706 | 0.1297 | 0.0971 | 0.0924 | 0.0866 | 0.1367 |
| 8 | 0.1279 | 0.0926 | 0.1179 | 0.1242 | 0.0777 | | | 0.0652 | 0.1276 | 0.0955 | 0.0921 | 0.0876 | 0.1364 |
| 9 | 0.1274 | 0.0953 | 0.1163 | 0.1263 | 0.0812 | | | 0.0618 | 0.1265 | 0.0968 | 0.0925 | 0.0923 | 0.1307 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 16 Weighted CDD

Weightings per Structural Worksheet 3 are applied to CDD values per Structural Worksheet 14.

| Weighted CDD | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.2430 | 0.0091 | 0.4884 | 0.0114 | 0.0092 | 0.4821 | 0.0009 | 0.0005 | 0.6184 | 0.0003 | 0.1276 | 0.0654 | 0.4290 | 0.0006 |
| 2 | 2.1258 | 0.0083 | 0.4448 | 0.0107 | 0.0097 | 0.4830 | 0.0008 | 0.0003 | 0.6050 | 0.0003 | 0.1225 | 0.0698 | 0.3701 | 0.0004 |
| 3 | 1.9997 | 0.0080 | 0.3583 | 0.0096 | 0.0087 | 0.4780 | 0.0005 | | 0.6010 | 0.0003 | 0.1168 | 0.0754 | 0.3428 | 0.0003 |
| 4 | 1.9780 | 0.0065 | 0.3323 | 0.0079 | 0.0078 | 0.4489 | 0.0004 | | 0.6608 | 0.0003 | 0.1121 | 0.0621 | 0.3386 | 0.0003 |
| 5 | 1.9997 | 0.0058 | 0.3188 | 0.0063 | 0.0064 | 0.4154 | 0.0002 | | 0.7727 | 0.0003 | 0.0907 | 0.0543 | 0.3285 | 0.0003 |
| 6 | 2.0275 | 0.0051 | 0.3323 | 0.0052 | 0.0060 | 0.4341 | | | 0.8031 | 0.0003 | 0.0795 | 0.0555 | 0.3062 | 0.0003 |
| 7 | 2.0206 | 0.0043 | 0.2954 | 0.0050 | 0.0048 | 0.4681 | | | 0.8228 | 0.0002 | 0.0634 | 0.0539 | 0.3026 | 0.0002 |
| 8 | 2.1168 | 0.0040 | 0.2691 | 0.0048 | 0.0049 | 0.5207 | | | 0.9047 | 0.0002 | 0.0574 | 0.0466 | 0.3042 | 0.0002 |
| 9 | 2.1175 | 0.0050 | 0.2350 | 0.0058 | 0.0058 | 0.4936 | | | 1.0137 | 0.0003 | 0.0610 | 0.0485 | 0.2486 | 0.0003 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 17 Structural Model Summary

The worksheet provides a summary of outputs calculated in other worksheets, at portfolio level, for each of the nine 7 year rolling windows. The undiversified values are calculated using the weighted standard deviation as per Structural Worksheet 4. Diversified values are calculated using a diversified standard deviation, obtained by correlating all assets with each other in the same manner used for Equity diversification, using the diversification methodology described in Section 3.4.1.

| | Total Debt $m | Total Assets $m | Undiversified Weighted Standard Deviation | Diversified Standard Deviation | Undiversified DD | Undiversified Calibrated PD | Diversified DD | Diversified Calibrated PD |
|---|---|---|---|---|---|---|---|---|
| 1 | 1228391 | 1522163 | 0.0278 | 0.0204 | 8.2566 | 0.0044 | 11.2594 | 0.0007 |
| 2 | 1228391 | 1522163 | 0.0298 | 0.0218 | 7.6114 | 0.0063 | 10.3961 | 0.0012 |
| 3 | 1228376 | 1521848 | 0.0320 | 0.0236 | 7.0968 | 0.0084 | 9.6191 | 0.0019 |
| 4 | 1228376 | 1521848 | 0.0333 | 0.0250 | 6.9816 | 0.0089 | 9.2802 | 0.0024 |
| 5 | 1228376 | 1521848 | 0.0330 | 0.0248 | 7.1955 | 0.0079 | 9.5557 | 0.0020 |
| 6 | 1227412 | 1520665 | 0.0321 | 0.0241 | 7.4780 | 0.0068 | 9.9490 | 0.0016 |
| 7 | 1227412 | 1520665 | 0.0319 | 0.0242 | 7.4237 | 0.0070 | 9.8140 | 0.0017 |
| 8 | 1227412 | 1520665 | 0.0312 | 0.0238 | 7.8385 | 0.0056 | 10.2735 | 0.0013 |
| 9 | 1227412 | 1520665 | 0.0300 | 0.0225 | 8.0430 | 0.0050 | 10.7169 | 0.0010 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 18    CPD: Parametric / Nonparametric Comparison

Nonparametric values are based on nonparametric CStdev as obtained in Structural Worksheet 13, whereas parametric is based on the tail 5% of the standard normal distribution, distribution using equation 2.33.

| Year | Parametric Cstdev | Parametric CDD | Parametric Calibrated CPD | Nonparametric CDD | Nonparametric Calibrated CPD |
|---|---|---|---|---|---|
| 1 | 0.0573 | 4.0037 | 0.0371 | 2.2430 | 0.0750 |
| 2 | 0.0614 | 3.6909 | 0.0424 | 2.1258 | 0.0783 |
| 3 | 0.0660 | 3.4414 | 0.0470 | 1.9997 | 0.0820 |
| 4 | 0.0686 | 3.3855 | 0.0481 | 1.9780 | 0.0827 |
| 5 | 0.0680 | 3.4892 | 0.0461 | 1.9997 | 0.0820 |
| 6 | 0.0662 | 3.6262 | 0.0436 | 2.0275 | 0.0812 |
| 7 | 0.0659 | 3.5999 | 0.0440 | 2.0206 | 0.0814 |
| 8 | 0.0643 | 3.8010 | 0.0405 | 2.1168 | 0.0786 |
| 9 | 0.0619 | 3.9002 | 0.0388 | 2.1175 | 0.0786 |

# Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 19 Standard Deviation – One Year

Standard deviation is calculated in the same manner as Structural Worksheet 2, but using 12 month data frames instead of 7 year rolling windows.

| | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard Deviation - one year | | | | | | | | | | | | | |
| 1 | 0.0207 | 0.0227 | 0.0319 | 0.0316 | 0.0213 | 0.0476 | 0.3609 | 0.0199 | 0.0294 | 0.0267 | 0.0384 | 0.0223 | 0.0418 |
| 2 | 0.0177 | 0.0217 | 0.0232 | 0.0214 | 0.0211 | 0.0386 | 0.2957 | 0.0148 | 0.0290 | 0.0210 | 0.0346 | 0.0215 | 0.0362 |
| 3 | 0.0172 | 0.0216 | 0.0285 | 0.0255 | 0.0210 | 0.0520 | | 0.0231 | 0.0237 | 0.0302 | 0.0296 | 0.0230 | 0.0372 |
| 4 | 0.0179 | 0.0306 | 0.0208 | 0.0238 | 0.0286 | 0.0480 | | 0.0245 | 0.0290 | 0.0250 | 0.0457 | 0.0294 | 0.0387 |
| 5 | 0.0217 | 0.0328 | 0.0256 | 0.0245 | 0.0327 | 0.0639 | | 0.0279 | 0.0363 | 0.0312 | 0.0501 | 0.0297 | 0.0414 |
| 6 | 0.0217 | 0.0326 | 0.0321 | 0.0248 | 0.0358 | | | 0.0370 | 0.0380 | 0.0339 | 0.0501 | 0.0280 | 0.0426 |
| 7 | 0.0279 | 0.0295 | 0.0173 | 0.0332 | 0.0328 | | | 0.0319 | 0.0311 | 0.0354 | 0.0331 | 0.0289 | 0.0574 |
| 8 | 0.0274 | 0.0416 | 0.0320 | 0.0296 | 0.0344 | | | 0.0315 | 0.0382 | 0.0328 | 0.0460 | 0.0420 | 0.0886 |
| 9 | 0.0204 | 0.0495 | 0.0287 | 0.0282 | 0.0319 | | | 0.0305 | 0.0290 | 0.0359 | 0.0438 | 0.0371 | 0.0380 |

## Appendix 3 continued. Structural Model – Sample (Banks)

Structural Worksheet 20 Weighted Standard Deviation – One Year

Weightings as per Structural Worksheet 3 are applied to the one year standard deviation in Structural Worksheet 19.

| | Total Portfolio | ADELAIDE BANK | AUS.AND NZ.BANKING GP. | BANK OF QLND. | BENDIGO BANK | COMMONWEALTH BK.OF AUS. | HOME BUILDING SOC. | MORTGAGE CHOICE | NATIONAL AUS.BANK | ROCK BUILDING SOCIETY | SAINT GEORGE BANK | SUNCORP-METWAY | WESTPAC BANKING | WIDE BAY AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weighted Standard Deviation - one year | | | | | | | | | | | | | | |
| 1 | 0.0225 | 0.0002 | 0.0046 | 0.0002 | 0.0003 | 0.0048 | 0.0000 | 0.0001 | 0.0055 | 0.0000 | 0.0015 | 0.0013 | 0.0040 | 0.0000 |
| 2 | 0.0201 | 0.0002 | 0.0043 | 0.0002 | 0.0002 | 0.0048 | 0.0000 | 0.0000 | 0.0041 | 0.0000 | 0.0012 | 0.0012 | 0.0038 | 0.0000 |
| 3 | 0.0230 | 0.0002 | 0.0041 | 0.0002 | 0.0002 | 0.0048 | 0.0000 | | 0.0066 | 0.0000 | 0.0017 | 0.0012 | 0.0040 | 0.0000 |
| 4 | 0.0281 | 0.0001 | 0.0058 | 0.0001 | 0.0002 | 0.0063 | 0.0000 | | 0.0074 | 0.0000 | 0.0014 | 0.0015 | 0.0052 | 0.0000 |
| 5 | 0.0308 | 0.0002 | 0.0058 | 0.0002 | 0.0002 | 0.0067 | 0.0000 | | 0.0097 | 0.0000 | 0.0016 | 0.0015 | 0.0051 | 0.0000 |
| 6 | 0.0346 | 0.0001 | 0.0058 | 0.0002 | 0.0002 | 0.0075 | | | 0.0133 | 0.0000 | 0.0016 | 0.0015 | 0.0044 | 0.0000 |
| 7 | 0.0313 | 0.0002 | 0.0052 | 0.0001 | 0.0002 | 0.0074 | | | 0.0109 | 0.0000 | 0.0015 | 0.0011 | 0.0047 | 0.0000 |
| 8 | 0.0361 | 0.0002 | 0.0067 | 0.0002 | 0.0002 | 0.0083 | | | 0.0109 | 0.0000 | 0.0012 | 0.0013 | 0.0070 | 0.0000 |
| 9 | 0.0352 | 0.0001 | 0.0074 | 0.0002 | 0.0002 | 0.0078 | | | 0.0112 | 0.0000 | 0.0014 | 0.0013 | 0.0055 | 0.0000 |

**Appendix 3 continued. Structural Model – Sample (Banks)**

Structural Worksheet 21 One year Summary

A summary of portfolio values for each of the nine years is provided, based on 12 month data frames.

| Year | Undiversified Weighted Standard Deviation | Undiversified DD | Undiversified Calibrated PD |
|---|---|---|---|
| 1 | 0.0225 | 10.1931 | 0.0014 |
| 2 | 0.0201 | 11.3099 | 0.0006 |
| 3 | 0.0230 | 9.8635 | 0.0017 |
| 4 | 0.0281 | 8.2710 | 0.0044 |
| 5 | 0.0308 | 7.7138 | 0.0060 |
| 6 | 0.0346 | 6.9326 | 0.0091 |
| 7 | 0.0313 | 7.5752 | 0.0065 |
| 8 | 0.0361 | 6.7749 | 0.0099 |
| 9 | 0.0352 | 6.8601 | 0.0095 |

# Appendix 4. Transition Model

## Worksheets

## Appendix 4 continued. Transition Matrix – Sample (All Industries)

Transition Worksheet 1 Data Sample and Calibrated Ratings

The worksheet shows data for a sample of companies. For confidentiality reasons, only listed companies are included in the sample. Ratings have been calibrated to S&P ratings as per the mapping in Table 2-5.

| Issuer | ASX Code | Calibrated Rating | Debt ($m) | Industry |
|---|---|---|---|---|
| Adelaide Bank Limited | ADB | BBB+ | 420.9 | Banks |
| Amcor Limited | AMC | BBB | 3055.0 | Other Materials |
| Ansell Limited | ANN | BB+ | 426.2 | Healthcare |
| ANZ Banking Group | ANZ | AA- | 72104.0 | Banks |
| Aristocrat | ALL | BB- | 172.4 | Other Consumer Discretionary |
| Australian Gas Light Company | AGL | A | 2034.0 | Utilities |
| AWB | AWB | BBB | 1071.8 | Food Beverage & Tobacco |
| Bank of Queensland Limited | BOQ | BBB+ | 1473.5 | Banks |
| Bendigo Bank Limited | BEN | BBB+ | 405.4 | Banks |
| BHP Billiton Limited | BHP | A+ | 10969.0 | Metals & Mining |
| Bonlac Foods Ltd | BFL | B+ | 265.4 | Food Beverage & Tobacco |
| Boral | BLD | BBB+ | 829.1 | Other Materials |
| Burns, Philp & Company Limited | BPC | B+ | 1119.0 | Food Beverage & Tobacco |
| Coca-Cola Amatil Limited | CCL | A- | 1839.6 | Food Beverage & Tobacco |

**Appendix 4 continued. Transition Model – Sample (All Industries)**

Transition Worksheet 2 Industry / Rating Matrix

The table shows aggregate debt values ($m) in each rating category, per industry.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| Banks | 3105 | 371880 | 23785 | 2300 | 0 | 0 | 0 | 0 |
| Diversified Financials | 13978 | 13971 | 43647 | 6253 | 925 | 3255 | 0 | 0 |
| Energy | 0 | 0 | 1428 | 4507 | 0 | 0 | 0 | 0 |
| Food Beverage & Tobacco | 0 | 806 | 7446 | 8823 | 0 | 4611 | 0 | 0 |
| Healthcare | 113 | 50 | 0 | 0 | 1226 | 0 | 0 | 0 |
| Insurance | 252 | 4206 | 7240 | 347 | 0 | 0 | 0 | 0 |
| Media | 0 | 0 | 5360 | 15947 | 1283 | 0 | 0 | 0 |
| Metals & Mining | 0 | 8070 | 22757 | 0 | 0 | 0 | 0 | 0 |
| Other Consumer Discretionary | 0 | 0 | 0 | 1916 | 172 | 187 | 0 | 0 |
| Other Materials | 0 | 0 | 0 | 10068 | 0 | 0 | 0 | 0 |
| Real Estate | 0 | 1551 | 8406 | 4108 | 0 | 0 | 0 | 0 |
| Telecommunication Services | 0 | 12555 | 21438 | 651 | 0 | 0 | 0 | 0 |
| Transportation | 1773 | 0 | 6278 | 20158 | 0 | 682 | 0 | 0 |
| Utilities | 4328 | 8455 | 9696 | 18443 | 0 | 0 | 0 | 0 |
| Total | 23550 | 421543 | 157482 | 93519 | 3605 | 8735 | 0 | 0 |

## Appendix 4 continued. Transition Model – Sample (All Industries)

Transition Worksheet 3 Probabilities and Forward Values

Probabilities are based on the S&P (2005b, p.12) global average one-year transition rates, 1981 - 2004 after adjusting for non-rated entities as explained in 2.5.4.2.1. Forward values obtained using a CreditMetrics example as explained in Section 3.3.3.

Probabilities

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| AAA | 91.64% | 7.72% | 0.48% | 0.09% | 0.06% | 0.00% | 0.00% | 0.00% |
| AA | 0.63% | 90.44% | 8.12% | 0.61% | 0.06% | 0.11% | 0.02% | 0.01% |
| A | 0.05% | 2.15% | 91.33% | 5.78% | 0.45% | 0.17% | 0.03% | 0.04% |
| BBB | 0.02% | 0.22% | 4.10% | 89.64% | 4.68% | 0.82% | 0.20% | 0.31% |
| BB | 0.04% | 0.09% | 0.36% | 5.79% | 83.27% | 8.09% | 1.03% | 1.32% |
| B | 0.00% | 0.08% | 0.23% | 0.32% | 5.88% | 82.29% | 4.77% | 6.44% |
| CCC/C | 0.09% | 0.00% | 0.35% | 0.45% | 1.50% | 11.13% | 53.53% | 32.95% |

| Forward Values | |
|---|---|
| AAA | 109.37 |
| AA | 109.19 |
| A | 108.66 |
| BBB | 107.55 |
| BB | 102.02 |
| B | 98.10 |
| CCC/C | 83.64 |
| D | 51.13 |

## Appendix 4 continued. Transition Model – Sample (Banks)

Transition Worksheet 4 Values

The table contains forward zero values on the left hand side (as per Transition Worksheet 3) which are multiplied by the debt values for Banks (Transition Worksheet 2) across the top of the table, for each rating category.

| | | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|---|
| | | 3105 | 371880 | 23785 | 2300 | 0 | 0 | 0 | 0 |
| AAA | 109.37 | 3396 | 406725 | 26014 | 2515 | 0 | 0 | 0 | 0 |
| AA | 109.19 | 3390 | 406056 | 25971 | 2511 | 0 | 0 | 0 | 0 |
| A | 108.66 | 3374 | 404085 | 25845 | 2499 | 0 | 0 | 0 | 0 |
| BBB | 107.55 | 3340 | 399957 | 25581 | 2473 | 0 | 0 | 0 | 0 |
| BB | 102.02 | 3168 | 379392 | 24266 | 2346 | 0 | 0 | 0 | 0 |
| B | 98.10 | 3046 | 364814 | 23334 | 2256 | 0 | 0 | 0 | 0 |
| CCC/C | 83.64 | 2597 | 311040 | 19894 | 1924 | 0 | 0 | 0 | 0 |
| D | 51.13 | 1588 | 190142 | 12161 | 1176 | 0 | 0 | 0 | 0 |

**Appendix 4 continued. Transition Model – Sample (Banks)**

Transition Worksheet 5 Probability Weighted Value

Values in Transition Worksheet 4 are multiplied by probabilities in Transition Worksheet 3, and aggregated to form a portfolio mean.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| AAA | 3112 | 2547 | 14 | 1 | 0 | 0 | 0 | 0 |
| AA | 262 | 367234 | 559 | 6 | 0 | 0 | 0 | 0 |
| A | 16 | 32813 | 23603 | 103 | 0 | 0 | 0 | 0 |
| BBB | 3 | 2421 | 1478 | 2217 | 0 | 0 | 0 | 0 |
| BB | 2 | 238 | 110 | 110 | 0 | 0 | 0 | 0 |
| B | 0 | 419 | 39 | 19 | 0 | 0 | 0 | 0 |
| CCC/C | 0 | 65 | 6 | 4 | 0 | 0 | 0 | 0 |
| D | 0 | 20 | 5 | 4 | 0 | 0 | 0 | 0 |
| mean | 3395 | 405757 | 25814 | 2462 | 0 | 0 | 0 | 0 |
| portfolio mean | 437427 | | | | | | | |

**Appendix 4 continued. Transition Model – Sample (Banks)**

Transition Worksheet 6 Distance from Mean Squared

We square the differences between the values in Transition Worksheet 4 and the mean for that category as per Transition Worksheet 5.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| AAA | 1 | 938140 | 40120 | 2870 | 0 | 0 | 0 | 0 |
| AA | 24 | 89516 | 24802 | 2443 | 0 | 0 | 0 | 0 |
| A | 454 | 2794819 | 987 | 1387 | 0 | 0 | 0 | 0 |
| BBB | 3111 | 33635811 | 54101 | 137 | 0 | 0 | 0 | 0 |
| BB | 51753 | 695092142 | 2396087 | 13332 | 0 | 0 | 0 | 0 |
| B | 121950 | 1676271462 | 6151984 | 42278 | 0 | 0 | 0 | 0 |
| CCC/C | 637149 | 8971146294 | 35042776 | 289620 | 0 | 0 | 0 | 0 |
| d | 3267762 | 46489529695 | 186386400 | 1653340 | 0 | 0 | 0 | 0 |

## Appendix 4 continued. Transition Model – Sample (Banks)

Transition Worksheet 7 Distance from Mean Squared x Probability

Figures in Transition Worksheet 6 are multiplied with corresponding probabilities in Transition Worksheet 3 and aggregated to form a variance for each rating category. Standard deviation is calculated as the square root of the variance for each category, and aggregated to form a portfolio standard deviation, from which VaR can be calculated using standard normal distribution tables.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| AAA | 0.49 | 5875.00 | 21.07 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 |
| AA | 1.82 | 80957.82 | 533.96 | 5.47 | 0.00 | 0.00 | 0.00 | 0.00 |
| A | 2.19 | 226945.99 | 901.76 | 56.90 | 0.00 | 0.00 | 0.00 | 0.00 |
| BBB | 2.93 | 203619.35 | 3124.90 | 123.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| BB | 32.54 | 435294.11 | 10820.39 | 623.62 | 0.00 | 0.00 | 0.00 | 0.00 |
| B | 0.00 | 1924536.70 | 10337.30 | 346.87 | 0.00 | 0.00 | 0.00 | 0.00 |
| CCC/C | 0.00 | 1872695.19 | 11040.57 | 586.34 | 0.00 | 0.00 | 0.00 | 0.00 |
| d | 0.00 | 4852262.78 | 78297.16 | 5108.88 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | | | |
| Variance | 39.98 | 9602186.94 | 115077.11 | 6851.70 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standard deviation | 6.32 | 3098.74 | 339.23 | 82.77 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | | | |
| portfolio stdev | 3527.07 | | | | | | | |

**Appendix 4 continued. Transition Model – Sample (Banks)**

Transition Worksheet 8 Joint Probabilities (AAA/AA sample)

Probabilities are obtained from Transition Worksheet 3. AAA probabilities (across the top) are multiplied with AA probabilities (down the left) to form joint probabilities.

| | | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|---|
| | | 91.64% | 7.72% | 0.48% | 0.09% | 0.06% | 0.00% | 0.00% | 0.00% |
| AAA | 0.63% | 0.57% | 0.05% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| AA | 90.44% | 82.88% | 6.99% | 0.44% | 0.09% | 0.06% | 0.00% | 0.00% | 0.00% |
| A | 8.12% | 7.44% | 0.63% | 0.04% | 0.01% | 0.01% | 0.00% | 0.00% | 0.00% |
| BBB | 0.61% | 0.55% | 0.05% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| BB | 0.06% | 0.06% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| B | 0.11% | 0.11% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CCC/C | 0.02% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| D | 0.01% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |

**Appendix 4 continued. Transition Model – Sample (Banks)**

Transition Worksheet 9 Joint Values

Values are obtained from Transition Worksheet 4. AAA values (across the top) are aggregated with AA values (down the left) to form joint values.

| | | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|---|
| | | 3396 | 3390 | 3374 | 3340 | 3168 | 3046 | 2597 | 1588 |
| AAA | 406725 | 410121 | 410116 | 410099 | 410065 | 409893 | 409771 | 409322 | 408313 |
| AA | 406056 | 409452 | 409446 | 409430 | 409395 | 409224 | 409102 | 408653 | 407643 |
| A | 404085 | 407481 | 407475 | 407459 | 407424 | 407253 | 407131 | 406682 | 405672 |
| BBB | 399957 | 403353 | 403347 | 403331 | 403296 | 403125 | 403003 | 402554 | 401545 |
| BB | 379392 | 382788 | 382782 | 382766 | 382731 | 382560 | 382438 | 381989 | 380980 |
| B | 364814 | 368210 | 368205 | 368188 | 368154 | 367982 | 367860 | 367411 | 366402 |
| CCC/C | 311040 | 314436 | 314431 | 314414 | 314380 | 314208 | 314087 | 313638 | 312628 |
| D | 190142 | 193538 | 193533 | 193516 | 193482 | 193310 | 193188 | 192739 | 191730 |

**Appendix 4 continued. Transition Model – Sample (Banks)**

Transition Worksheet 10 Joint Probability Weighted Values

Joint values in Transition Worksheet 9 are multiplied by joint probabilities in Transition Worksheet 8, and aggregated to form a joint portfolio mean.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| AAA | 2354 | 198 | 12 | 2 | 2 | 0 | 0 | 0 |
| AA | 339337 | 28601 | 1785 | 349 | 233 | 0 | 0 | 0 |
| A | 30321 | 2556 | 160 | 31 | 21 | 0 | 0 | 0 |
| BBB | 2238 | 189 | 12 | 2 | 2 | 0 | 0 | 0 |
| BB | 220 | 19 | 1 | 0 | 0 | 0 | 0 | 0 |
| B | 387 | 33 | 2 | 0 | 0 | 0 | 0 | 0 |
| CCC/C | 60 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| D | 19 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| mean | 374935 | 31601 | 1972 | 386 | 257 | 0 | 0 | 0 |
| portfolio mean | 409152 | | | | | | | |

## Appendix 4 continued. Transition Model – Sample (Banks)

Transition Worksheet 11 Joint Distance from Mean Squared

We square the differences between the joint values in Transition Worksheet 9 and the mean for that category as per Transition Worksheet 10.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| AAA | 939564 | 928760 | 897310 | 833200 | 549205 | 383610 | 29023 | 704121 |
| AA | 89956 | 86635 | 77218 | 59250 | 5141 | 2502 | 249025 | 2275581 |
| A | 2792363 | 2811074 | 2866530 | 2984429 | 3607203 | 4084381 | 6100839 | 12106688 |
| BBB | 33627288 | 33692142 | 33883465 | 34285914 | 36326313 | 37808389 | 43531691 | 57871533 |
| BB | 695053398 | 695348137 | 696216343 | 698036417 | 707139396 | 713627858 | 737818594 | 793678234 |
| B | 1676211294 | 1676668990 | 1678017012 | 1680841985 | 1694951350 | 1704988642 | 1742270217 | 1827561612 |
| CCC/C | 8971007101 | 8972065907 | 8975183864 | 8981715681 | 9014292480 | 9037420612 | 9122991354 | 9316849887 |
| D | 46489212832 | 46491623096 | 46498720346 | 46513586155 | 46587682752 | 46640242639 | 46834380520 | 47272327411 |

**Appendix 4 continued. Transition Model – Sample (Banks)**

Transition Worksheet 12 Joint Distance from Mean Squared x Probability

Figures in Transition Worksheet 11 are multiplied with corresponding joint probabilities in Transition Worksheet 8 and aggregated to form a variance for each rating category. Standard deviation is calculated as the square root of the variance for each category, and aggregated to form a joint portfolio standard deviation, from which VaR can be calculated using standard normal distribution tables.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| AAA | 5392 | 449 | 27 | 5 | 2 | 0 | 0 | 0 |
| AA | 74552 | 6052 | 337 | 51 | 3 | 0 | 0 | 0 |
| A | 207784 | 17631 | 1122 | 229 | 184 | 0 | 0 | 0 |
| BBB | 186543 | 15753 | 989 | 196 | 138 | 0 | 0 | 0 |
| BB | 398868 | 33633 | 2102 | 412 | 278 | 0 | 0 | 0 |
| B | 1763524 | 148682 | 9287 | 1820 | 1224 | 0 | 0 | 0 |
| CCC/C | 1716055 | 144657 | 9032 | 1768 | 1183 | 0 | 0 | 0 |
| D | 4446436 | 374793 | 23396 | 4579 | 3058 | 0 | 0 | 0 |
| Variance | 8799154 | 741651 | 46292 | 9060 | 6070 | 0 | 0 | 0 |
| Stdev | 2966 | 861 | 215 | 95 | 78 | 0 | 0 | 0 |
| pair variance | 9602227 | | | | | | | |
| pair stdev | 3099 | | | | | | | |

## Appendix 4 continued. Transition Model Sample (Banks)

Transition Worksheet 13 Monte Carlo Simulation – Random Number Generation

20,000 random numbers have been generated for every company in every industry. The table below shows a small sample of Banks. For reasons of confidentiality, the sample only shows information for listed banks where information is publicly available.

| Adelaide Bank Limited | ANZ Banking Group | Bank of Queensland Limited | Bendigo Bank Limited | Commonwealth Bank of Australia | National Australia Bank Limited | St. George Bank | Westpac Banking Corporation |
|---|---|---|---|---|---|---|---|
| BBB | AA | BBB | BBB | AA | AA | A | AA |
| 0.4324 | -1.5963 | 0.4511 | 0.6510 | -1.8554 | -0.6830 | 1.6232 | 2.0996 |
| 1.0096 | -1.2172 | 0.3079 | 1.7179 | -0.3241 | -0.4105 | -1.7352 | -0.4482 |
| -2.6988 | 2.2662 | 0.9394 | 0.6667 | -1.7243 | -1.5289 | 0.2182 | 1.0892 |
| 0.7451 | 0.8769 | -0.2148 | -0.7103 | 0.4261 | -1.7556 | -0.8148 | 0.5592 |
| 0.7515 | 0.5276 | 0.0303 | 0.1403 | 1.1071 | 1.2542 | 0.0756 | -2.8665 |
| 0.3432 | 0.7976 | -0.6977 | 0.9294 | -0.6129 | -0.6600 | -0.9193 | 1.0681 |
| 2.0187 | -0.8643 | 0.6180 | -0.9649 | 0.0059 | 0.6532 | 0.7693 | -0.2470 |
| -0.1746 | -1.6962 | -1.2585 | 0.5586 | -0.8854 | 2.1903 | 1.7014 | 0.7152 |
| 0.2969 | -0.0851 | -0.0377 | 0.2071 | 1.6633 | 0.2724 | -0.4309 | -1.5294 |
| -0.9894 | 0.2076 | 3.1816 | 1.2996 | -0.2045 | -0.7291 | 0.0936 | -0.1802 |
| 0.4938 | 0.0459 | 0.7452 | 0.8417 | -0.7915 | -0.0310 | -0.8683 | 2.1439 |
| 0.9379 | -0.2551 | 1.4616 | -0.2593 | 1.7864 | 2.6817 | 1.4341 | 1.0560 |

**Appendix 4 continued. Transition Model – Sample (Banks)**

Transition Worksheet 14 Monte Carlo Simulation – Mapping to Ratings

The random numbers shown in Transition Worksheet 13 are mapped to ratings using the mapping in Table 2-12.

| Adelaide Bank Limited | ANZ Banking Group | Bank of Queensland Limited | Bendigo Bank Limited | Commonwealth Bank of Australia | National Australia Bank Limited | St. George Bank | Westpac Banking Corporation |
|---|---|---|---|---|---|---|---|
| BBB | AA | BBB | BBB | AA | AA | A | AA |
| bbb | a | bbb | bbb | a | aa | a | aa |
| bbb | aa | bbb | a | aa | aa | bbb | aa |
| ccc | aa | bbb | bbb | a | a | a | aa |
| bbb | aa | bbb | bbb | aa | a | a | aa |
| bbb | aa | bbb | bbb | aa | aa | a | bb |
| bbb | aa | bbb | bbb | aa | aa | a | aa |
| a | aa | bbb | bbb | aa | aa | a | aa |
| bbb | a | bbb | bbb | aa | aa | a | aa |
| bbb | aa | bbb | bbb | aa | aa | a | a |
| bbb | aa | aa | bbb | aa | aa | a | aa |
| bbb | aa | bbb | bbb | aa | aa | a | aa |
| bbb | aa | bbb | bbb | aa | aaa | a | aa |

## Appendix 4 continued. Transition Model – CVaR Modelling

Transition Worksheet 15 Monte Carlo Portfolio – Percentage in Each Category

The worksheet shows the percentage ratings in each category for the entire portfolio, following 20,000 simulations and mapping each simulation to a rating category as per Table 2-12.

| | AAA | AA | A | BBB | BB | B | CCC | D |
|---|---|---|---|---|---|---|---|---|
| Banks | 1.26% | 84.19% | 12.89% | 1.39% | 0.12% | 0.11% | 0.03% | 0.02% |
| Diversified Financials | 15.77% | 17.88% | 50.42% | 10.09% | 1.76% | 3.54% | 0.23% | 0.31% |
| Energy | 0.03% | 0.69% | 25.09% | 69.33% | 3.73% | 0.69% | 0.18% | 0.26% |
| Food Beverage & Tobacco | 0.06% | 4.18% | 33.38% | 38.56% | 3.37% | 17.86% | 1.16% | 1.43% |
| Healthcare | 7.52% | 3.93% | 0.65% | 5.13% | 73.43% | 7.23% | 0.88% | 1.23% |
| Insurance | 2.25% | 34.45% | 56.26% | 6.34% | 0.46% | 0.17% | 0.04% | 0.03% |
| Media | 0.03% | 0.73% | 24.64% | 64.76% | 8.25% | 1.08% | 0.17% | 0.34% |
| Metals & Mining | 0.22% | 25.27% | 69.54% | 4.38% | 0.38% | 0.16% | 0.03% | 0.03% |
| Other Consumer Discretionary | 0.03% | 0.16% | 3.43% | 76.19% | 10.61% | 8.09% | 0.61% | 0.88% |
| Other Materials | 0.02% | 0.22% | 4.06% | 89.57% | 4.81% | 0.80% | 0.20% | 0.32% |
| Real Estate | 0.11% | 11.33% | 56.72% | 29.68% | 1.63% | 0.37% | 0.07% | 0.10% |
| Telecommunication Services | 0.26% | 34.12% | 59.51% | 5.50% | 0.39% | 0.16% | 0.02% | 0.04% |
| Transportation | 5.65% | 1.10% | 22.79% | 63.79% | 3.50% | 2.54% | 0.25% | 0.39% |
| Utilities | 9.84% | 20.13% | 25.22% | 41.89% | 2.22% | 0.43% | 0.10% | 0.15% |

## Appendix 4 continued. Transition Model – CVaR Modelling

Transition Worksheet 16 Monte Carlo CVaR – Percentage in Each Category

The worksheet shows the percentage ratings in each category for the CVaR (worst 5%) portfolio, following the simulations and mapping undertaken in Transition Worksheet 15.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| Banks | 0.00% | 0.00% | 66.76% | 27.77% | 2.40% | 2.25% | 0.52% | 0.30% |
| Diversified Financials | 0.00% | 0.00% | 0.00% | 0.00% | 18.34% | 70.78% | 4.64% | 6.24% |
| Energy | 0.00% | 0.00% | 0.00% | 2.82% | 74.56% | 13.90% | 3.58% | 5.14% |
| Food Beverage & Tobacco | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 48.20% | 23.10% | 28.70% |
| Healthcare | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 57.96% | 17.52% | 24.52% |
| Insurance | 0.00% | 0.00% | 0.00% | 86.21% | 9.12% | 3.33% | 0.70% | 0.64% |
| Media | 0.00% | 0.00% | 0.00% | 0.00% | 68.09% | 21.61% | 3.45% | 6.85% |
| Metals & Mining | 0.00% | 0.00% | 0.60% | 87.59% | 7.54% | 3.14% | 0.61% | 0.52% |
| Other Consumer Discretionary | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 70.22% | 12.11% | 17.68% |
| Other Materials | 0.00% | 0.00% | 0.00% | 0.00% | 73.54% | 15.99% | 4.07% | 6.40% |
| Real Estate | 0.00% | 0.00% | 0.00% | 56.58% | 32.53% | 7.39% | 1.40% | 2.09% |
| Telecommunication Services | 0.00% | 0.00% | 0.00% | 87.69% | 7.83% | 3.29% | 0.47% | 0.73% |
| Transportation | 0.00% | 0.00% | 0.00% | 0.00% | 36.37% | 50.81% | 4.96% | 7.86% |
| Utilities | 0.00% | 0.00% | 0.00% | 41.79% | 44.48% | 8.58% | 2.10% | 3.06% |

## Appendix 4 continued. Transition Model – CVaR Modelling

Transition Worksheet 17 Monte Carlo CVaR – Probability Weighted Values

Percentages in Transition Worksheet 16 are multiplied by forward values in Transition Worksheet 3, and summed to provide a mean for each industry in the final column.

| | AAA | AA | A | BBB | BB | B | CCC/C | D | Total |
|---|---|---|---|---|---|---|---|---|---|
| Banks | 0.0000 | 0.0000 | 0.7254 | 0.2987 | 0.0245 | 0.0221 | 0.0043 | 0.0016 | 1.0765 |
| Diversified Financials | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1871 | 0.6943 | 0.0388 | 0.0319 | 0.9522 |
| Energy | 0.0000 | 0.0000 | 0.0000 | 0.0303 | 0.7607 | 0.1364 | 0.0300 | 0.0263 | 0.9836 |
| Food Beverage & Tobacco | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.4729 | 0.1932 | 0.1467 | 0.8128 |
| Healthcare | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.5686 | 0.1465 | 0.1254 | 0.8405 |
| Insurance | 0.0000 | 0.0000 | 0.0000 | 0.9272 | 0.0930 | 0.0327 | 0.0059 | 0.0033 | 1.0620 |
| Media | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.6946 | 0.2120 | 0.0289 | 0.0350 | 0.9705 |
| Metals & Mining | 0.0000 | 0.0000 | 0.0065 | 0.9421 | 0.0769 | 0.0308 | 0.0051 | 0.0027 | 1.0640 |
| Other Consumer Discretionary | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.6888 | 0.1013 | 0.0904 | 0.8805 |
| Other Materials | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.7502 | 0.1569 | 0.0340 | 0.0327 | 0.9739 |
| Real Estate | 0.0000 | 0.0000 | 0.0000 | 0.6085 | 0.3319 | 0.0725 | 0.0117 | 0.0107 | 1.0354 |
| Telecommunication Services | 0.0000 | 0.0000 | 0.0000 | 0.9431 | 0.0799 | 0.0323 | 0.0039 | 0.0037 | 1.0628 |
| Transportation | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.3710 | 0.4984 | 0.0415 | 0.0402 | 0.9512 |
| Utilities | 0.0000 | 0.0000 | 0.0000 | 0.4495 | 0.4537 | 0.0841 | 0.0176 | 0.0156 | 1.0205 |

## Appendix 4 continued. Transition Model – CVaR Modelling

Transition Worksheet 18 Monte Carlo Portfolio – Difference from Mean

The worksheet calculates the square root of the variance between the forward values in Transition Worksheet 3 and the mean in Transition Worksheet 17.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| Banks | 1.72 | 1.54 | 1.01 | 0.10 | 5.63 | 9.55 | 24.01 | 56.52 |
| Diversified Financials | 14.15 | 13.97 | 13.44 | 12.33 | 6.80 | 2.88 | 11.58 | 44.09 |
| Energy | 11.01 | 10.83 | 10.30 | 9.19 | 3.66 | 0.26 | 14.72 | 47.23 |
| Food Beverage & Tobacco | 28.09 | 27.91 | 27.38 | 26.27 | 20.74 | 16.82 | 2.36 | 30.15 |
| Healthcare | 25.32 | 25.14 | 24.61 | 23.50 | 17.97 | 14.05 | 0.41 | 32.92 |
| Insurance | 3.17 | 2.99 | 2.46 | 1.35 | 4.18 | 8.10 | 22.56 | 55.07 |
| Media | 12.32 | 12.14 | 11.61 | 10.50 | 4.97 | 1.05 | 13.41 | 45.92 |
| Metals & Mining | 2.97 | 2.79 | 2.26 | 1.15 | 4.38 | 8.30 | 22.76 | 55.27 |
| Other Consumer Discretionary | 21.32 | 21.14 | 20.61 | 19.50 | 13.97 | 10.05 | 4.41 | 36.92 |
| Other Materials | 11.98 | 11.80 | 11.27 | 10.16 | 4.63 | 0.71 | 13.75 | 46.26 |
| Real Estate | 5.83 | 5.65 | 5.12 | 4.01 | 1.52 | 5.44 | 19.90 | 52.41 |
| Telecommunication Services | 3.09 | 2.91 | 2.38 | 1.27 | 4.26 | 8.18 | 22.64 | 55.15 |
| Transportation | 14.25 | 14.07 | 13.54 | 12.43 | 6.90 | 2.98 | 11.48 | 43.99 |
| Utilities | 7.32 | 7.14 | 6.61 | 5.50 | 0.03 | 3.95 | 18.41 | 50.92 |

**Appendix 4 continued. Transition Model – CVaR Modelling**

Transition Worksheet 19 Monte Carlo CVaR – Probability Weighted Difference

Differences in Transition Worksheet 18 are multiplied by percentages in Transition Worksheet 16.

| | AAA | AA | A | BBB | BB | B | CCC/C | D | Total (CVaR) |
|---|---|---|---|---|---|---|---|---|---|
| Banks | 0.0000 | 0.0000 | 0.0067 | 0.0003 | 0.0014 | 0.0021 | 0.0012 | 0.0017 | 0.0135 |
| Diversified Financials | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0125 | 0.0204 | 0.0054 | 0.0275 | 0.0658 |
| Energy | 0.0000 | 0.0000 | 0.0000 | 0.0026 | 0.0273 | 0.0004 | 0.0053 | 0.0243 | 0.0598 |
| Food Beverage & Tobacco | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0811 | 0.0054 | 0.0865 | 0.1730 |
| Healthcare | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0814 | 0.0007 | 0.0807 | 0.1629 |
| Insurance | 0.0000 | 0.0000 | 0.0000 | 0.0116 | 0.0038 | 0.0027 | 0.0016 | 0.0035 | 0.0232 |
| Media | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0338 | 0.0023 | 0.0046 | 0.0315 | 0.0722 |
| Metals & Mining | 0.0000 | 0.0000 | 0.0001 | 0.0100 | 0.0033 | 0.0026 | 0.0014 | 0.0029 | 0.0204 |
| Other Consumer Discretionary | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0706 | 0.0053 | 0.0653 | 0.1412 |
| Other Materials | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0341 | 0.0011 | 0.0056 | 0.0296 | 0.0704 |
| Real Estate | 0.0000 | 0.0000 | 0.0000 | 0.0227 | 0.0049 | 0.0040 | 0.0028 | 0.0110 | 0.0454 |
| Telecommunication Services | 0.0000 | 0.0000 | 0.0000 | 0.0111 | 0.0033 | 0.0027 | 0.0011 | 0.0040 | 0.0222 |
| Transportation | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0251 | 0.0152 | 0.0057 | 0.0346 | 0.0805 |
| Utilities | 0.0000 | 0.0000 | 0.0000 | 0.0230 | 0.0001 | 0.0034 | 0.0039 | 0.0156 | 0.0459 |

## Appendix 4 continued. Transition Model – CVaR Modelling

Transition Worksheet 20 Analytical Portfolio

The worksheet shows the dollar ($m) spread of the total portfolio in a years time (prior to multiplying by forward values), by multiplying probabilities in Transition Worksheet 3 by the values in Transition Worksheet 2.

| | AAA | AA | A | BBB | BB | B | CCC/C | D | Total |
|---|---|---|---|---|---|---|---|---|---|
| Banks | 5187 | 337083 | 52029 | 5690 | 450 | 486 | 90 | 56 | 401070 |
| Diversified Financials | 12921 | 14672 | 41330 | 8288 | 1468 | 2894 | 194 | 261 | 82029 |
| Energy | 2 | 41 | 1489 | 4123 | 217 | 39 | 10 | 15 | 5935 |
| Food Beverage & Tobacco | 11 | 912 | 7238 | 8359 | 718 | 3880 | 240 | 327 | 21685 |
| Healthcare | 104 | 55 | 9 | 71 | 1021 | 99 | 13 | 16 | 1388 |
| Insurance | 262 | 3980 | 6969 | 755 | 52 | 20 | 4 | 5 | 12046 |
| Media | 7 | 152 | 5554 | 14679 | 1838 | 244 | 47 | 68 | 22589 |
| Metals & Mining | 62 | 7788 | 21438 | 1363 | 108 | 48 | 9 | 10 | 30827 |
| Other Consumer Discretionary | 0 | 5 | 80 | 1728 | 244 | 184 | 15 | 20 | 2275 |
| Other Materials | 2 | 23 | 413 | 9025 | 471 | 83 | 20 | 31 | 10068 |
| Real Estate | 15 | 1593 | 7971 | 4177 | 231 | 50 | 11 | 16 | 14065 |
| Telecommunication Services | 90 | 11818 | 20624 | 1898 | 135 | 56 | 11 | 12 | 34643 |
| Transportation | 1633 | 318 | 6570 | 18436 | 1012 | 737 | 75 | 109 | 28891 |
| Utilities | 4028 | 8231 | 10319 | 17148 | 915 | 177 | 42 | 62 | 40923 |
| Total | 24325 | 386670 | 182034 | 95740 | 8880 | 8996 | 781 | 1009 | 708435 |

## Appendix 4 continued. Transition Model – CVaR Modelling

Transition Worksheet 21 Analytical CVaR Portfolio

The table shows the worst 5% of the values in Transition Worksheet 20.

| | AAA | AA | A | BBB | BB | B | CCC/C | D | Total |
|---|---|---|---|---|---|---|---|---|---|
| Banks | 0 | 0 | 13283 | 5690 | 450 | 486 | 90 | 56 | 20054 |
| Diversified Financials | 0 | 0 | 0 | 0 | 752 | 2894 | 194 | 261 | 4101 |
| Energy | 0 | 0 | 0 | 16 | 217 | 39 | 10 | 15 | 297 |
| Food Beverage & Tobacco | 0 | 0 | 0 | 0 | 0 | 516 | 240 | 327 | 1084 |
| Healthcare | 0 | 0 | 0 | 0 | 0 | 41 | 13 | 16 | 69 |
| Insurance | 0 | 0 | 0 | 522 | 52 | 20 | 4 | 5 | 602 |
| Media | 0 | 0 | 0 | 0 | 770 | 244 | 47 | 68 | 1129 |
| Metals & Mining | 0 | 0 | 3 | 1363 | 108 | 48 | 9 | 10 | 1541 |
| Other Consumer Discretionary | 0 | 0 | 0 | 0 | 0 | 79 | 15 | 20 | 114 |
| Other Materials | 0 | 0 | 0 | 0 | 369 | 83 | 20 | 31 | 503 |
| Real Estate | 0 | 0 | 0 | 395 | 231 | 50 | 11 | 16 | 703 |
| Telecommunication Services | 0 | 0 | 0 | 1518 | 135 | 56 | 11 | 12 | 1732 |
| Transportation | 0 | 0 | 0 | 0 | 523 | 737 | 75 | 109 | 1445 |
| Utilities | 0 | 0 | 0 | 850 | 915 | 177 | 42 | 62 | 2046 |

## Appendix 4 continued. Transition Model – CVaR Modelling

Transition Worksheet 22 Analytical CVaR – Percentage in Each Category

The table shows the percentage ratings in each category for the values in Transition Worksheet 21.

| | AAA | AA | A | BBB | BB | B | CCC/C | D |
|---|---|---|---|---|---|---|---|---|
| Banks | 0.00% | 0.00% | 66.24% | 28.37% | 2.24% | 2.42% | 0.45% | 0.28% |
| Diversified Financials | 0.00% | 0.00% | 0.00% | 0.00% | 18.33% | 70.57% | 4.74% | 6.36% |
| Energy | 0.00% | 0.00% | 0.00% | 5.40% | 73.21% | 13.27% | 3.23% | 4.89% |
| Food Beverage & Tobacco | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 47.63% | 22.17% | 30.20% |
| Healthcare | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 58.43% | 18.27% | 23.31% |
| Insurance | 0.00% | 0.00% | 0.00% | 86.72% | 8.59% | 3.29% | 0.64% | 0.76% |
| Media | 0.00% | 0.00% | 0.00% | 0.00% | 68.19% | 21.57% | 4.18% | 6.06% |
| Metals & Mining | 0.00% | 0.00% | 0.22% | 88.45% | 7.00% | 3.08% | 0.57% | 0.67% |
| Other Consumer Discretionary | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 69.37% | 12.83% | 17.80% |
| Other Materials | 0.00% | 0.00% | 0.00% | 0.00% | 73.36% | 16.41% | 4.05% | 6.18% |
| Real Estate | 0.00% | 0.00% | 0.00% | 56.15% | 32.86% | 7.05% | 1.61% | 2.33% |
| Telecommunication Services | 0.00% | 0.00% | 0.00% | 87.65% | 7.80% | 3.22% | 0.62% | 0.71% |
| Transportation | 0.00% | 0.00% | 0.00% | 0.00% | 36.23% | 51.02% | 5.21% | 7.54% |
| Utilities | 0.00% | 0.00% | 0.00% | 41.55% | 44.69% | 8.67% | 2.06% | 3.03% |

## Appendix 4 continued. Transition Model – CVaR Modelling

Transition Worksheet 23 Analytical CVaR - Probability Weighted Values

Values in Transition Worksheet 21 are multiplied by probabilities in Transition Worksheet 22 and summed to form the mean for each industry.

| | AAA | AA | A | BBB | BB | B | CCC/C | D | Total |
|---|---|---|---|---|---|---|---|---|---|
| Banks | 0.00 | 0.00 | 71.97 | 30.51 | 2.29 | 2.38 | 0.37 | 0.14 | 107.67 |
| Diversified Financials | 0.00 | 0.00 | 0.00 | 0.00 | 18.70 | 69.23 | 3.96 | 3.25 | 95.14 |
| Energy | 0.00 | 0.00 | 0.00 | 5.81 | 74.69 | 13.02 | 2.70 | 2.50 | 98.71 |
| Food Beverage & Tobacco | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 46.72 | 18.54 | 15.44 | 80.71 |
| Healthcare | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 57.32 | 15.28 | 11.92 | 84.51 |
| Insurance | 0.00 | 0.00 | 0.00 | 93.27 | 8.76 | 3.23 | 0.54 | 0.39 | 106.18 |
| Media | 0.00 | 0.00 | 0.00 | 0.00 | 69.56 | 21.16 | 3.50 | 3.10 | 97.32 |
| Metals & Mining | 0.00 | 0.00 | 0.24 | 95.13 | 7.14 | 3.02 | 0.48 | 0.35 | 106.36 |
| Other Consumer Discretionary | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 68.05 | 10.73 | 9.10 | 87.88 |
| Other Materials | 0.00 | 0.00 | 0.00 | 0.00 | 74.84 | 16.10 | 3.39 | 3.16 | 97.49 |
| Real Estate | 0.00 | 0.00 | 0.00 | 60.39 | 33.52 | 6.92 | 1.34 | 1.19 | 103.37 |
| Telecommunication Services | 0.00 | 0.00 | 0.00 | 94.27 | 7.96 | 3.16 | 0.52 | 0.36 | 106.27 |
| Transportation | 0.00 | 0.00 | 0.00 | 0.00 | 36.96 | 50.06 | 4.36 | 3.85 | 95.23 |
| Utilities | 0.00 | 0.00 | 0.00 | 44.69 | 45.60 | 8.50 | 1.72 | 1.55 | 102.06 |

**Appendix 4 continued. Transition Model – CVaR Modelling**

Transition Worksheet 24 Analytical CVaR – Difference from Mean

The worksheet calculates the square root of the variance between the forward values in Transition Worksheet 3 and the mean in Transition Worksheet 23.

| | AAA | AA | A | BBB | BB | B | CCC/C | D | Total |
|---|---|---|---|---|---|---|---|---|---|
| Banks | 1.70 | 1.52 | 0.99 | 0.12 | 5.65 | 9.57 | 24.03 | 56.54 | 100.12 |
| Diversified Financials | 14.23 | 14.05 | 13.52 | 12.41 | 6.88 | 2.96 | 11.50 | 44.01 | 119.54 |
| Energy | 10.66 | 10.48 | 9.95 | 8.84 | 3.31 | 0.61 | 15.07 | 47.58 | 106.49 |
| Food Beverage & Tobacco | 28.66 | 28.48 | 27.95 | 26.84 | 21.31 | 17.39 | 2.93 | 29.58 | 183.15 |
| Healthcare | 24.86 | 24.68 | 24.15 | 23.04 | 17.51 | 13.59 | 0.87 | 33.38 | 162.07 |
| Insurance | 3.19 | 3.01 | 2.48 | 1.37 | 4.16 | 8.08 | 22.54 | 55.05 | 99.88 |
| Media | 12.05 | 11.87 | 11.34 | 10.23 | 4.70 | 0.78 | 13.68 | 46.19 | 110.83 |
| Metals & Mining | 3.01 | 2.83 | 2.30 | 1.19 | 4.34 | 8.26 | 22.72 | 55.23 | 99.88 |
| Other Consumer Discretionary | 21.49 | 21.31 | 20.78 | 19.67 | 14.14 | 10.22 | 4.24 | 36.75 | 148.59 |
| Other Materials | 11.88 | 11.70 | 11.17 | 10.06 | 4.53 | 0.61 | 13.85 | 46.36 | 110.17 |
| Real Estate | 6.00 | 5.82 | 5.29 | 4.18 | 1.35 | 5.27 | 19.73 | 52.24 | 99.88 |
| Telecommunication Services | 3.10 | 2.92 | 2.39 | 1.28 | 4.25 | 8.17 | 22.63 | 55.14 | 99.88 |
| Transportation | 14.14 | 13.96 | 13.43 | 12.32 | 6.79 | 2.87 | 11.59 | 44.10 | 119.21 |
| Utilities | 7.31 | 7.13 | 6.60 | 5.49 | 0.04 | 3.96 | 18.42 | 50.93 | 99.88 |

**Appendix 4 continued. Transition Model – CVaR Modelling**

Transition Worksheet 25 Analytical CVaR - Probability Weighted Difference

Differences in Transition Worksheet 24 are multiplied by percentages in Transition Worksheet 22.

| | AAA | AA | A | BBB | BB | B | CCC/C | D | Total (CVaR) |
|---|---|---|---|---|---|---|---|---|---|
| Banks | 0 | 0 | 0.65713 | 0.03345 | 0.12669 | 0.23178 | 0.10757 | 0.15764 | 1.31% |
| Diversified Financials | 0 | 0 | 0 | 0 | 1.26026 | 2.08548 | 0.5448 | 2.80094 | 6.69% |
| Energy | 0 | 0 | 0 | 0.47696 | 2.42011 | 0.08152 | 0.48633 | 2.32922 | 5.79% |
| Food Beverage & Tobacco | 0 | 0 | 0 | 0 | 0 | 8.28322 | 0.64991 | 8.93314 | 17.87% |
| Healthcare | 0 | 0 | 0 | 0 | 0 | 7.93937 | 0.15918 | 7.78019 | 15.88% |
| Insurance | 0 | 0 | 0 | 1.18457 | 0.35757 | 0.26632 | 0.14454 | 0.41614 | 2.37% |
| Media | 0 | 0 | 0 | 0 | 3.20369 | 0.16794 | 0.57212 | 2.79951 | 6.74% |
| Metals & Mining | 0 | 0 | 0.00513 | 1.05587 | 0.30334 | 0.25446 | 0.1305 | 0.37271 | 2.12% |
| Other Consumer Discretionary | 0 | 0 | 0 | 0 | 0 | 7.08716 | 0.54434 | 6.54282 | 14.17% |
| Other Materials | 0 | 0 | 0 | 0 | 3.32511 | 0.1005 | 0.56069 | 2.86493 | 6.85% |
| Real Estate | 0 | 0 | 0 | 2.34836 | 0.44286 | 0.3716 | 0.31668 | 1.21722 | 4.70% |
| Telecommunication Services | 0 | 0 | 0 | 1.12606 | 0.33113 | 0.26292 | 0.13966 | 0.39235 | 2.25% |
| Transportation | 0 | 0 | 0 | 0 | 2.46089 | 1.46602 | 0.60419 | 3.32272 | 7.85% |
| Utilities | 0 | 0 | 0 | 2.28171 | 0.01732 | 0.34306 | 0.37949 | 1.54183 | 4.56% |

## Appendix 4 continued. Transition Model – CVaR Modelling

Transition Worksheet 26 Portfolio Contribution Method

Following 20,000 simulations and mapping each simulation to a rating category as per Table 2-12, we calculate the worst 5% of all returns. In this case it works out to all the BB – D ratings in our Monte Carlo portfolio and a portion of the BBB ratings. Each industry's contribution to the worst 5% is shown in the final column.

| | AAA | AA | A | BBB | BB | B | CCC/C | D | Total | % of Portfolio |
|---|---|---|---|---|---|---|---|---|---|---|
| Banks | 0 | 0 | 0 | 916 | 482 | 451 | 104 | 61 | 2014 | 5.69% |
| Diversified Financials | 0 | 0 | 0 | 1362 | 1440 | 2903 | 191 | 256 | 6151 | 17.38% |
| Energy | 0 | 0 | 0 | 677 | 221 | 41 | 11 | 15 | 965 | 2.73% |
| Food Beverage & Tobacco | 0 | 0 | 0 | 1375 | 731 | 3873 | 250 | 311 | 6541 | 18.48% |
| Healthcare | 0 | 0 | 0 | 12 | 1019 | 100 | 12 | 17 | 1161 | 3.28% |
| Insurance | 0 | 0 | 0 | 120 | 53 | 19 | 4 | 4 | 200 | 0.57% |
| Media | 0 | 0 | 0 | 2405 | 1863 | 244 | 39 | 77 | 4629 | 13.08% |
| Metals & Mining | 0 | 0 | 0 | 222 | 116 | 48 | 9 | 8 | 404 | 1.14% |
| Other Consumer Discretionary | 0 | 0 | 0 | 285 | 241 | 184 | 14 | 20 | 744 | 2.10% |
| Other Materials | 0 | 0 | 0 | 1483 | 484 | 81 | 20 | 32 | 2100 | 5.93% |
| Real Estate | 0 | 0 | 0 | 686 | 229 | 52 | 10 | 15 | 992 | 2.80% |
| Telecommunication Services | 0 | 0 | 0 | 313 | 136 | 57 | 8 | 13 | 527 | 1.49% |
| Transportation | 0 | 0 | 0 | 3030 | 1011 | 734 | 72 | 114 | 4961 | 14.02% |
| Utilities | 0 | 0 | 0 | 2819 | 910 | 175 | 43 | 63 | 4010 | 11.33% |
| Total | 0 | 0 | 0 | 15705 | 8936 | 8963 | 787 | 1005 | 35397 | 100% |

# Appendix 5. Industry Summaries - Equity Model

This Appendix shows a summary of key outputs for each industry, using our Equity model, with each industry shown in a separate table. The bottom section of each table shows historical data for each of the nine 7 year rolling windows. Year 1 represents data for years 1-7, year 2 for years 3-8 and so on, through to year nine which is for years 9-15.

## Appendix 5 continued. Industry Summaries – Equity Model

1 Automobiles & Components; Banks

| Automobiles & Components | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 5 |
| Aggregate Market Capitalisation ($m) | | | | 940.2 |
| Undiversified Standard Deviation | | | | 0.32933 |
| Undiversified VaR | | | | 0.54174 |
| Diversified Standard Deviation | | | | 0.18299 |
| Diversified VaR | | | | 0.30102 |
| Daily CVaR | | | | 0.04295 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.30102 | 0.54174 | 0.03426 | 0.04295 |
| Year 2 | 0.27876 | 0.52316 | 0.03309 | 0.04148 |
| Year 3 | 0.27542 | 0.50759 | 0.03210 | 0.04024 |
| Year 4 | 0.29458 | 0.50839 | 0.03215 | 0.04031 |
| Year 5 | 0.30748 | 0.51130 | 0.03234 | 0.04054 |
| Year 6 | 0.31263 | 0.47723 | 0.03018 | 0.03784 |
| Year 7 | 0.32615 | 0.47455 | 0.03001 | 0.03762 |
| Year 8 | 0.34487 | 0.46035 | 0.02911 | 0.03650 |
| Year 9 | 0.30797 | 0.44529 | 0.02816 | 0.03531 |

| Banks | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 13 |
| Aggregate Market Capitalisation ($m) | | | | 238,683.6 |
| Undiversified Standard Deviation | | | | 0.18418 |
| Undiversified VaR | | | | 0.30297 |
| Diversified Standard Deviation | | | | 0.13560 |
| Diversified VaR | | | | 0.22305 |
| Daily CVaR | | | | 0.02402 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.22305 | 0.30297 | 0.01916 | 0.02402 |
| Year 2 | 0.23458 | 0.32065 | 0.02028 | 0.02542 |
| Year 3 | 0.25418 | 0.34213 | 0.02164 | 0.02713 |
| Year 4 | 0.27543 | 0.36219 | 0.02291 | 0.02872 |
| Year 5 | 0.27725 | 0.36464 | 0.02306 | 0.02891 |
| Year 6 | 0.26744 | 0.35545 | 0.02248 | 0.02818 |
| Year 7 | 0.26878 | 0.35246 | 0.02229 | 0.02795 |
| Year 8 | 0.26175 | 0.34522 | 0.02183 | 0.02737 |
| Year 9 | 0.25273 | 0.33844 | 0.02140 | 0.02683 |

## Appendix 5 continued. Industry Summaries - Equity Model

2 Capital Goods; Chemicals

| Capital Goods | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 27 |
| Aggregate Market Capitalisation ($m) | | | | 29,655.0 |
| Undiversified Standard Deviation | | | | 0.27911 |
| Undiversified VaR | | | | 0.45913 |
| Diversified Standard Deviation | | | | 0.14402 |
| Diversified VaR | | | | 0.23692 |
| Daily CVaR | | | | 0.03640 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.23692 | 0.45913 | 0.02904 | 0.03640 |
| Year 2 | 0.26247 | 0.46391 | 0.02934 | 0.03678 |
| Year 3 | 0.26575 | 0.48207 | 0.03049 | 0.03822 |
| Year 4 | 0.28778 | 0.49646 | 0.03140 | 0.03936 |
| Year 5 | 0.29158 | 0.48259 | 0.03052 | 0.03826 |
| Year 6 | 0.28637 | 0.47823 | 0.03025 | 0.03792 |
| Year 7 | 0.26305 | 0.56140 | 0.03551 | 0.04451 |
| Year 8 | 0.25619 | 0.49703 | 0.03144 | 0.03941 |
| Year 9 | 0.26538 | 0.49495 | 0.03130 | 0.03924 |

| Chemicals | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 6 |
| Aggregate Market Capitalisation ($m) | | | | 10,622.6 |
| Undiversified Standard Deviation | | | | 0.25622 |
| Undiversified VaR | | | | 0.42149 |
| Diversified Standard Deviation | | | | 0.18881 |
| Diversified VaR | | | | 0.31059 |
| Daily CVaR | | | | 0.03342 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.31059 | 0.42149 | 0.02666 | 0.03342 |
| Year 2 | 0.30261 | 0.42633 | 0.02696 | 0.03380 |
| Year 3 | 0.28790 | 0.40896 | 0.02587 | 0.03243 |
| Year 4 | 0.32508 | 0.43646 | 0.02760 | 0.03461 |
| Year 5 | 0.33375 | 0.45990 | 0.02909 | 0.03646 |
| Year 6 | 0.29436 | 0.45848 | 0.02900 | 0.03635 |
| Year 7 | 0.29274 | 0.43462 | 0.02749 | 0.03446 |
| Year 8 | 0.29586 | 0.42719 | 0.02702 | 0.03387 |
| Year 9 | 0.29292 | 0.42735 | 0.02703 | 0.03388 |

**Appendix 5 continued. Industry Summaries - Equity Model**

3 Commercial Services & Supplies; Construction Materials

| Commercial Services & Supplies | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 26 |
| Aggregate Market Capitalisation ($m) | | | | 30,874.9 |
| Undiversified Standard Deviation | | | | 0.32706 |
| Undiversified VaR | | | | 0.53801 |
| Diversified Standard Deviation | | | | 0.14735 |
| Diversified VaR | | | | 0.24239 |
| Daily CVaR | | | | 0.04266 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.24239 | 0.53801 | 0.03403 | 0.04266 |
| Year 2 | 0.21996 | 0.52910 | 0.03346 | 0.04195 |
| Year 3 | 0.24231 | 0.57634 | 0.03645 | 0.04570 |
| Year 4 | 0.25729 | 0.60119 | 0.03802 | 0.04767 |
| Year 5 | 0.26456 | 0.55905 | 0.03536 | 0.04433 |
| Year 6 | 0.27619 | 0.50737 | 0.03209 | 0.04023 |
| Year 7 | 0.28454 | 0.49811 | 0.03150 | 0.03949 |
| Year 8 | 0.27428 | 0.44481 | 0.02813 | 0.03527 |
| Year 9 | 0.26773 | 0.43553 | 0.02755 | 0.03453 |

| Construction Materials | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 5 |
| Aggregate Market Capitalisation ($m) | | | | 26,321.4 |
| Undiversified Standard Deviation | | | | 0.26891 |
| Undiversified VaR | | | | 0.44235 |
| Diversified Standard Deviation | | | | 0.19426 |
| Diversified VaR | | | | 0.31955 |
| Daily CVaR | | | | 0.03507 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.31955 | 0.44235 | 0.02798 | 0.03507 |
| Year 2 | 0.29046 | 0.42514 | 0.02689 | 0.03371 |
| Year 3 | 0.28513 | 0.44026 | 0.02784 | 0.03491 |
| Year 4 | 0.28692 | 0.45871 | 0.02901 | 0.03637 |
| Year 5 | 0.34609 | 0.51617 | 0.03265 | 0.04093 |
| Year 6 | 0.31651 | 0.49243 | 0.03114 | 0.03904 |
| Year 7 | 0.31428 | 0.49749 | 0.03146 | 0.03944 |
| Year 8 | 0.38741 | 0.50998 | 0.03225 | 0.04043 |
| Year 9 | 0.37036 | 0.48953 | 0.03096 | 0.03881 |

**Appendix 5 continued. Industry Summaries - Equity Model**

4 Consumer Durables & Apparel; Diversified Financials

| Consumer Durables & Apparel | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 7 |
| Aggregate Market Capitalisation ($m) | | | | 4,301.5 |
| Undiversified Standard Deviation | | | | 0.32180 |
| Undiversified VaR | | | | 0.52935 |
| Diversified Standard Deviation | | | | 0.23712 |
| Diversified VaR | | | | 0.39006 |
| Daily CVaR | | | | 0.04197 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.39006 | 0.52935 | 0.03348 | 0.04197 |
| Year 2 | 0.39108 | 0.55933 | 0.03538 | 0.04435 |
| Year 3 | 0.33388 | 0.61585 | 0.03895 | 0.04883 |
| Year 4 | 0.38193 | 0.67022 | 0.04239 | 0.05314 |
| Year 5 | 0.44304 | 0.64981 | 0.04110 | 0.05152 |
| Year 6 | 0.45493 | 0.67668 | 0.04280 | 0.05365 |
| Year 7 | 0.27616 | 0.46299 | 0.02928 | 0.03671 |
| Year 8 | 0.43296 | 0.69970 | 0.04425 | 0.05548 |
| Year 9 | 0.38862 | 0.64247 | 0.04063 | 0.05094 |

| Diversified Financials | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 40 |
| Aggregate Market Capitalisation ($m) | | | | 51,827.8 |
| Undiversified Standard Deviation | | | | 0.25195 |
| Undiversified VaR | | | | 0.41446 |
| Diversified Standard Deviation | | | | 0.12208 |
| Diversified VaR | | | | 0.20082 |
| Daily CVaR | | | | 0.03286 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.20082 | 0.41446 | 0.02621 | 0.03286 |
| Year 2 | 0.20319 | 0.42732 | 0.02703 | 0.03388 |
| Year 3 | 0.18894 | 0.44528 | 0.02816 | 0.03530 |
| Year 4 | 0.22567 | 0.48010 | 0.03036 | 0.03806 |
| Year 5 | 0.22428 | 0.48709 | 0.03081 | 0.03862 |
| Year 6 | 0.25123 | 0.48549 | 0.03071 | 0.03849 |
| Year 7 | 0.27976 | 0.54622 | 0.03455 | 0.04331 |
| Year 8 | 0.26026 | 0.53823 | 0.03404 | 0.04267 |
| Year 9 | 0.24888 | 0.47058 | 0.02976 | 0.03731 |

**Appendix 5 continued. Industry Summaries - Equity Model**

5 Energy; Food & Staples Retailing

| Energy | |
|---|---|
| Number of Companies | 34 |
| Aggregate Market Capitalisation ($m) | 80,045.5 |
| Undiversified Standard Deviation | 0.35890 |
| Undiversified VaR | 0.59040 |
| Diversified Standard Deviation | 0.17373 |
| Diversified VaR | 0.28578 |
| Daily CVaR | 0.04681 |

| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
|---|---|---|---|---|
| Year 1 | 0.28578 | 0.59040 | 0.03734 | 0.04681 |
| Year 2 | 0.25484 | 0.59045 | 0.03734 | 0.04681 |
| Year 3 | 0.26280 | 0.59207 | 0.03745 | 0.04694 |
| Year 4 | 0.28891 | 0.56890 | 0.03598 | 0.04511 |
| Year 5 | 0.29944 | 0.56076 | 0.03547 | 0.04446 |
| Year 6 | 0.29498 | 0.55666 | 0.03521 | 0.04414 |
| Year 7 | 0.31080 | 0.54195 | 0.03428 | 0.04297 |
| Year 8 | 0.30057 | 0.55196 | 0.03491 | 0.04376 |
| Year 9 | 0.28249 | 0.52414 | 0.03315 | 0.04156 |

| Food & Staples Retailing | |
|---|---|
| Number of Companies | 6 |
| Aggregate Market Capitalisation ($m) | 44,119.5 |
| Undiversified Standard Deviation | 0.22655 |
| Undiversified VaR | 0.37268 |
| Diversified Standard Deviation | 0.14950 |
| Diversified VaR | 0.24593 |
| Daily CVaR | 0.02955 |

| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
|---|---|---|---|---|
| Year 1 | 0.24593 | 0.37268 | 0.02357 | 0.02955 |
| Year 2 | 0.25242 | 0.39425 | 0.02493 | 0.03126 |
| Year 3 | 0.26517 | 0.41496 | 0.02624 | 0.03290 |
| Year 4 | 0.29771 | 0.43607 | 0.02758 | 0.03457 |
| Year 5 | 0.30039 | 0.43507 | 0.02752 | 0.03450 |
| Year 6 | 0.27432 | 0.42769 | 0.02705 | 0.03391 |
| Year 7 | 0.29684 | 0.37218 | 0.02354 | 0.02951 |
| Year 8 | 0.28715 | 0.36338 | 0.02298 | 0.02881 |
| Year 9 | 0.28392 | 0.35261 | 0.02230 | 0.02796 |

**Appendix 5 continued. Industry Summaries - Equity Model**

6 Food Beverage & Tobacco; Healthcare Equipment & Services

| Food Beverage & Tobacco | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 15 |
| Aggregate Market Capitalisation ($m) | | | | 26,733.8 |
| Undiversified Standard Deviation | | | | 0.24240 |
| Undiversified VaR | | | | 0.39874 |
| Diversified Standard Deviation | | | | 0.12292 |
| Diversified VaR | | | | 0.20220 |
| Daily CVaR | | | | 0.03161 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.20220 | 0.39874 | 0.02522 | 0.03161 |
| Year 2 | 0.22409 | 0.45480 | 0.02876 | 0.03606 |
| Year 3 | 0.26043 | 0.52211 | 0.03302 | 0.04140 |
| Year 4 | 0.29589 | 0.58226 | 0.03683 | 0.04617 |
| Year 5 | 0.29763 | 0.55321 | 0.03499 | 0.04386 |
| Year 6 | 0.28557 | 0.52335 | 0.03310 | 0.04149 |
| Year 7 | 0.29664 | 0.54756 | 0.03463 | 0.04341 |
| Year 8 | 0.29659 | 0.51831 | 0.03278 | 0.04110 |
| Year 9 | 0.30146 | 0.49367 | 0.03122 | 0.03914 |

| Healthcare Equipment & Services | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 17 |
| Aggregate Market Capitalisation ($m) | | | | 16,099.1 |
| Undiversified Standard Deviation | | | | 0.31889 |
| Undiversified VaR | | | | 0.52457 |
| Diversified Standard Deviation | | | | 0.13818 |
| Diversified VaR | | | | 0.22731 |
| Daily CVaR | | | | 0.04159 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.22731 | 0.52457 | 0.03318 | 0.04159 |
| Year 2 | 0.22188 | 0.56180 | 0.03553 | 0.04454 |
| Year 3 | 0.23304 | 0.60747 | 0.03842 | 0.04816 |
| Year 4 | 0.25679 | 0.63015 | 0.03985 | 0.04996 |
| Year 5 | 0.25036 | 0.60070 | 0.03799 | 0.04763 |
| Year 6 | 0.27854 | 0.59924 | 0.03790 | 0.04751 |
| Year 7 | 0.28799 | 0.58624 | 0.03708 | 0.04648 |
| Year 8 | 0.28394 | 0.56128 | 0.03550 | 0.04450 |
| Year 9 | 0.26807 | 0.49382 | 0.03123 | 0.03915 |

**Appendix 5 continued. Industry Summaries - Equity Model**

7 Hotels Restaurants & Leisure; Insurance

| Hotels Restaurants & Leisure | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 10 |
| Aggregate Market Capitalisation ($m) | | | | 20,165.3 |
| Undiversified Standard Deviation | | | | 0.31292 |
| Undiversified VaR | | | | 0.51475 |
| Diversified Standard Deviation | | | | 0.19137 |
| Diversified VaR | | | | 0.31481 |
| Daily CVaR | | | | 0.04081 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.31481 | 0.51475 | 0.03256 | 0.04081 |
| Year 2 | 0.31261 | 0.55171 | 0.03489 | 0.04374 |
| Year 3 | 0.28215 | 0.50425 | 0.03189 | 0.03998 |
| Year 4 | 0.27625 | 0.48551 | 0.03071 | 0.03849 |
| Year 5 | 0.27766 | 0.48545 | 0.03070 | 0.03849 |
| Year 6 | 0.29476 | 0.51381 | 0.03250 | 0.04074 |
| Year 7 | 0.29659 | 0.52899 | 0.03346 | 0.04194 |
| Year 8 | 0.29435 | 0.53972 | 0.03413 | 0.04279 |
| Year 9 | 0.31531 | 0.40557 | 0.02565 | 0.03216 |

| Insurance | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 7 |
| Aggregate Market Capitalisation ($m) | | | | 58,984.9 |
| Undiversified Standard Deviation | | | | 0.32621 |
| Undiversified VaR | | | | 0.53661 |
| Diversified Standard Deviation | | | | 0.20524 |
| Diversified VaR | | | | 0.33763 |
| Daily CVaR | | | | 0.04255 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.33763 | 0.53661 | 0.03394 | 0.04255 |
| Year 2 | 0.33254 | 0.53917 | 0.03410 | 0.04275 |
| Year 3 | 0.34177 | 0.56249 | 0.03558 | 0.04460 |
| Year 4 | 0.33996 | 0.56501 | 0.03573 | 0.04480 |
| Year 5 | 0.33718 | 0.49895 | 0.03156 | 0.03956 |
| Year 6 | 0.32599 | 0.45312 | 0.02866 | 0.03593 |
| Year 7 | 0.33580 | 0.47770 | 0.03021 | 0.03787 |
| Year 8 | 0.33777 | 0.44401 | 0.02808 | 0.03520 |
| Year 9 | 0.43641 | 0.53929 | 0.03411 | 0.04276 |

**Appendix 5 continued. Industry Summaries - Equity Model**

8 Media; Metals & Mining

| Media | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 18 |
| Aggregate Market Capitalisation ($m) | | | | 32,306.3 |
| Undiversified Standard Deviation | | | | 0.27728 |
| Undiversified VaR | | | | 0.45613 |
| Diversified Standard Deviation | | | | 0.14087 |
| Diversified VaR | | | | 0.23173 |
| Daily CVaR | | | | 0.03616 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.23173 | 0.45613 | 0.02885 | 0.03616 |
| Year 2 | 0.22989 | 0.46757 | 0.02957 | 0.03707 |
| Year 3 | 0.25039 | 0.49108 | 0.03106 | 0.03894 |
| Year 4 | 0.25621 | 0.48946 | 0.03096 | 0.03881 |
| Year 5 | 0.26053 | 0.47108 | 0.02979 | 0.03735 |
| Year 6 | 0.25009 | 0.46403 | 0.02935 | 0.03679 |
| Year 7 | 0.29978 | 0.54064 | 0.03419 | 0.04287 |
| Year 8 | 0.24911 | 0.47204 | 0.02985 | 0.03743 |
| Year 9 | 0.24952 | 0.43784 | 0.02769 | 0.03472 |

| Metals & Mining | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 64 |
| Aggregate Market Capitalisation ($m) | | | | 207,728.3 |
| Undiversified Standard Deviation | | | | 0.34014 |
| Undiversified VaR | | | | 0.55953 |
| Diversified Standard Deviation | | | | 0.20562 |
| Diversified VaR | | | | 0.33825 |
| Daily CVaR | | | | 0.04436 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.33825 | 0.55953 | 0.03539 | 0.04436 |
| Year 2 | 0.32087 | 0.55681 | 0.03522 | 0.04415 |
| Year 3 | 0.32335 | 0.58292 | 0.03687 | 0.04622 |
| Year 4 | 0.32046 | 0.58120 | 0.03676 | 0.04608 |
| Year 5 | 0.32297 | 0.56710 | 0.03587 | 0.04496 |
| Year 6 | 0.30716 | 0.53622 | 0.03391 | 0.04251 |
| Year 7 | 0.31758 | 0.59001 | 0.03732 | 0.04678 |
| Year 8 | 0.29663 | 0.54014 | 0.03416 | 0.04283 |
| Year 9 | 0.28125 | 0.53506 | 0.03384 | 0.04242 |

**Appendix 5 continued. Industry Summaries - Equity Model**

9 Paper & Forest Products; Pharmaceuticals & Biotechnology

| Paper & Forest Products | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 8 |
| Aggregate Market Capitalisation ($m) | | | | 5,373.3 |
| Undiversified Standard Deviation | | | | 0.40807 |
| Undiversified VaR | | | | 0.67128 |
| Diversified Standard Deviation | | | | 0.21959 |
| Diversified VaR | | | | 0.36123 |
| Daily CVaR | | | | 0.05322 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.36123 | 0.67128 | 0.04246 | 0.05322 |
| Year 2 | 0.34594 | 0.66125 | 0.04182 | 0.05243 |
| Year 3 | 0.31255 | 0.62200 | 0.03934 | 0.04932 |
| Year 4 | 0.30559 | 0.55837 | 0.03531 | 0.04427 |
| Year 5 | 0.32475 | 0.52560 | 0.03324 | 0.04167 |
| Year 6 | 0.32986 | 0.53808 | 0.03403 | 0.04266 |
| Year 7 | 0.32405 | 0.54850 | 0.03469 | 0.04349 |
| Year 8 | 0.43108 | 0.65313 | 0.04131 | 0.05178 |
| Year 9 | 0.31782 | 0.53208 | 0.03365 | 0.04219 |

| Pharmaceuticals & Biotechnology | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 23 |
| Aggregate Market Capitalisation ($m) | | | | 16,993.2 |
| Undiversified Standard Deviation | | | | 0.40908 |
| Undiversified VaR | | | | 0.67293 |
| Diversified Standard Deviation | | | | 0.22620 |
| Diversified VaR | | | | 0.37209 |
| Daily CVaR | | | | 0.05335 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.37209 | 0.67293 | 0.04256 | 0.05335 |
| Year 2 | 0.34370 | 0.74367 | 0.04703 | 0.05896 |
| Year 3 | 0.33763 | 0.82947 | 0.05246 | 0.06577 |
| Year 4 | 0.35545 | 0.95524 | 0.06041 | 0.07574 |
| Year 5 | 0.39011 | 0.80726 | 0.05106 | 0.06400 |
| Year 6 | 0.39095 | 0.63681 | 0.04028 | 0.05049 |
| Year 7 | 0.37830 | 0.71233 | 0.04505 | 0.05648 |
| Year 8 | 0.31917 | 0.66310 | 0.04194 | 0.05257 |
| Year 9 | 0.28571 | 0.57258 | 0.03621 | 0.04540 |

**Appendix 5 continued. Industry Summaries - Equity Model**

10 Real Estate; Retailing

| Real Estate | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 54 |
| Aggregate Market Capitalisation ($m) | | | | 115,323.7 |
| Undiversified Standard Deviation | | | | 0.23898 |
| Undiversified VaR | | | | 0.39312 |
| Diversified Standard Deviation | | | | 0.11243 |
| Diversified VaR | | | | 0.18495 |
| Daily CVaR | | | | 0.03117 |

| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
|---|---|---|---|---|
| Year 1 | 0.18495 | 0.39312 | 0.02486 | 0.03117 |
| Year 2 | 0.19578 | 0.41389 | 0.02618 | 0.03282 |
| Year 3 | 0.19970 | 0.41948 | 0.02653 | 0.03326 |
| Year 4 | 0.21875 | 0.41795 | 0.02643 | 0.03314 |
| Year 5 | 0.21852 | 0.40996 | 0.02593 | 0.03250 |
| Year 6 | 0.23297 | 0.40124 | 0.02538 | 0.03181 |
| Year 7 | 0.21450 | 0.42947 | 0.02716 | 0.03405 |
| Year 8 | 0.19300 | 0.39578 | 0.02503 | 0.03138 |
| Year 9 | 0.18979 | 0.38775 | 0.02452 | 0.03074 |

| Retailing | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 20 |
| Aggregate Market Capitalisation ($m) | | | | 9,534.9 |
| Undiversified Standard Deviation | | | | 0.30864 |
| Undiversified VaR | | | | 0.50771 |
| Diversified Standard Deviation | | | | 0.17146 |
| Diversified VaR | | | | 0.28206 |
| Daily CVaR | | | | 0.04025 |

| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
|---|---|---|---|---|
| Year 1 | 0.28206 | 0.50771 | 0.03211 | 0.04025 |
| Year 2 | 0.26038 | 0.49635 | 0.03139 | 0.03935 |
| Year 3 | 0.23056 | 0.45781 | 0.02895 | 0.03630 |
| Year 4 | 0.32130 | 0.54324 | 0.03436 | 0.04307 |
| Year 5 | 0.33156 | 0.53490 | 0.03383 | 0.04241 |
| Year 6 | 0.34594 | 0.51438 | 0.03253 | 0.04078 |
| Year 7 | 0.34553 | 0.47618 | 0.03012 | 0.03775 |
| Year 8 | 0.31475 | 0.44388 | 0.02807 | 0.03519 |
| Year 9 | 0.29073 | 0.42727 | 0.02702 | 0.03388 |

**Appendix 5 continued. Industry Summaries - Equity Model**

11 Software & Services; Technology Hardware & Equipment

| Software & Services | |
|---|---|
| Number of Companies | 18 |
| Aggregate Market Capitalisation ($m) | 8,844.7 |
| Undiversified Standard Deviation | 0.51136 |
| Undiversified VaR | 0.84119 |
| Diversified Standard Deviation | 0.26465 |
| Diversified VaR | 0.43535 |
| Daily CVaR | 0.06669 |

| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
|---|---|---|---|---|
| Year 1 | 0.43535 | 0.84119 | 0.05320 | 0.06669 |
| Year 2 | 0.43742 | 0.90976 | 0.05754 | 0.07213 |
| Year 3 | 0.40045 | 0.95147 | 0.06018 | 0.07544 |
| Year 4 | 0.43262 | 1.02896 | 0.06508 | 0.08158 |
| Year 5 | 0.41722 | 0.93159 | 0.05892 | 0.07386 |
| Year 6 | 0.42224 | 0.82453 | 0.05215 | 0.06537 |
| Year 7 | 1.04870 | 1.48547 | 0.09395 | 0.11778 |
| Year 8 | 0.97538 | 1.50708 | 0.09532 | 0.11949 |
| Year 9 | 0.57797 | 0.83931 | 0.05308 | 0.06655 |

| Technology Hardware & Equipment | |
|---|---|
| Number of Companies | 9 |
| Aggregate Market Capitalisation ($m) | 1,944.3 |
| Undiversified Standard Deviation | 0.57838 |
| Undiversified VaR | 0.95143 |
| Diversified Standard Deviation | 0.29526 |
| Diversified VaR | 0.48570 |
| Daily CVaR | 0.07544 |

| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
|---|---|---|---|---|
| Year 1 | 0.48570 | 0.95143 | 0.06017 | 0.07544 |
| Year 2 | 0.38004 | 0.88614 | 0.05604 | 0.07026 |
| Year 3 | 0.40171 | 0.93421 | 0.05908 | 0.07407 |
| Year 4 | 0.52776 | 0.99733 | 0.06308 | 0.07907 |
| Year 5 | 0.69251 | 0.98125 | 0.06206 | 0.07780 |
| Year 6 | 0.69295 | 0.93563 | 0.05917 | 0.07418 |
| Year 7 | 0.77451 | 0.86888 | 0.05495 | 0.06889 |
| Year 8 | 0.70323 | 0.83632 | 0.05289 | 0.06631 |
| Year 9 | 0.63471 | 0.77578 | 0.04906 | 0.06151 |

**Appendix 5 continued. Industry Summaries - Equity Model**

12 Telecommunication Services; Transportation

| Telecommunication Services | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 6 |
| Aggregate Market Capitalisation ($m) | | | | 48,911.1 |
| Undiversified Standard Deviation | | | | 0.22129 |
| Undiversified VaR | | | | 0.36403 |
| Diversified Standard Deviation | | | | 0.21002 |
| Diversified VaR | | | | 0.34548 |
| Daily CVaR | | | | 0.02886 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.34548 | 0.36403 | 0.02302 | 0.02886 |
| Year 2 | 0.35969 | 0.38206 | 0.02416 | 0.03029 |
| Year 3 | 0.42828 | 0.45840 | 0.02899 | 0.03635 |
| Year 4 | 0.45525 | 0.49250 | 0.03115 | 0.03905 |
| Year 5 | 0.48361 | 0.50901 | 0.03219 | 0.04036 |
| Year 6 | 0.51196 | 0.54765 | 0.03464 | 0.04342 |
| Year 7 | 0.51637 | 0.74071 | 0.04685 | 0.05873 |
| Year 8 | 0.51633 | 0.65549 | 0.04146 | 0.05197 |
| Year 9 | 0.65062 | 0.73275 | 0.04634 | 0.05810 |

| Transportation | | | | |
|---|---|---|---|---|
| Number of Companies | | | | 10 |
| Aggregate Market Capitalisation ($m) | | | | 38,520.8 |
| Undiversified Standard Deviation | | | | 0.28768 |
| Undiversified VaR | | | | 0.47324 |
| Diversified Standard Deviation | | | | 0.14823 |
| Diversified VaR | | | | 0.24384 |
| Daily CVaR | | | | 0.03752 |
| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
| Year 1 | 0.24384 | 0.47324 | 0.02993 | 0.03752 |
| Year 2 | 0.24480 | 0.48280 | 0.03053 | 0.03828 |
| Year 3 | 0.25290 | 0.48791 | 0.03086 | 0.03868 |
| Year 4 | 0.28076 | 0.51843 | 0.03279 | 0.04110 |
| Year 5 | 0.27071 | 0.53520 | 0.03385 | 0.04243 |
| Year 6 | 0.28407 | 0.49907 | 0.03156 | 0.03957 |
| Year 7 | 0.27688 | 0.46276 | 0.02927 | 0.03669 |
| Year 8 | 0.28570 | 0.42888 | 0.02712 | 0.03400 |
| Year 9 | 0.27679 | 0.42326 | 0.02677 | 0.03356 |

**Appendix 5 continued. Industry Summaries - Equity Model**

13 Utilities

| Utilities | |
|---|---|
| Number of Companies | 10 |
| Aggregate Market Capitalisation ($m) | 16,932.7 |
| Undiversified Standard Deviation | 0.22959 |
| Undiversified VaR | 0.37768 |
| Diversified Standard Deviation | 0.12370 |
| Diversified VaR | 0.20349 |
| Daily CVaR | 0.02994 |

| | Annual Diversified VaR | Annual Undiversified VaR: | Daily Undiversified VaR | CVaR |
|---|---|---|---|---|
| Year 1 | 0.20349 | 0.37768 | 0.02389 | 0.02994 |
| Year 2 | 0.18457 | 0.38335 | 0.02425 | 0.03039 |
| Year 3 | 0.20602 | 0.39476 | 0.02497 | 0.03130 |
| Year 4 | 0.20597 | 0.42614 | 0.02695 | 0.03379 |
| Year 5 | 0.27135 | 0.43903 | 0.02777 | 0.03481 |
| Year 6 | 0.28049 | 0.46217 | 0.02923 | 0.03664 |
| Year 7 | 0.31180 | 0.48029 | 0.03038 | 0.03808 |
| Year 8 | 0.29992 | 0.49292 | 0.03118 | 0.03908 |
| Year 9 | 0.31575 | 0.45614 | 0.02885 | 0.03617 |

# Appendix 6. Industry Summaries – Structural Model

This Appendix shows a summary of key outputs for each industry, using our Structural model, with each industry shown in a separate table. The bottom section of each table shows historical data for each of the nine 7 year rolling windows. Year 1 represents data for years 1-7, year 2 for years 3-8 and so on, through to year nine which is for years 9-15.

**Appendix 6 continued. Industry Summaries - Structural Model**

1 Automobiles & Components; Banks

| Automobiles & Components | | | |
|---|---|---|---|
| Number of Companies | | | 5 |
| Total Debt ($m) | | | 689.3 |
| Undiversified Standard Deviation | | | 0.16986 |
| Undiversified Calibrated PD | | | 0.01628 |
| Diversified Standard Deviation | | | 0.09442 |
| Diversified Calibrated PD | | | 0.00116 |
| Calibrated CPD | | | 0.06044 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00116 | 0.01628 | 0.06044 |
| Year 2 | 0.00071 | 0.01448 | 0.05777 |
| Year 3 | 0.00026 | 0.01046 | 0.05108 |
| Year 4 | 0.00041 | 0.01061 | 0.05135 |
| Year 5 | 0.00071 | 0.01071 | 0.05153 |
| Year 6 | 0.00112 | 0.01057 | 0.05127 |
| Year 7 | 0.00182 | 0.01080 | 0.05170 |
| Year 8 | 0.00118 | 0.00696 | 0.04390 |
| Year 9 | 0.00143 | 0.00681 | 0.04354 |

| Banks | | | |
|---|---|---|---|
| Number of Companies | | | 13 |
| Total Debt ($m) | | | 1,228,390.8 |
| Undiversified Standard Deviation | | | 0.02779 |
| Undiversified Calibrated PD | | | 0.00440 |
| Diversified Standard Deviation | | | 0.02038 |
| Diversified Calibrated PD | | | 0.00067 |
| Calibrated CPD | | | 0.03714 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00067 | 0.00440 | 0.03714 |
| Year 2 | 0.00118 | 0.00633 | 0.04240 |
| Year 3 | 0.00194 | 0.00838 | 0.04701 |
| Year 4 | 0.00240 | 0.00891 | 0.04810 |
| Year 5 | 0.00202 | 0.00795 | 0.04610 |
| Year 6 | 0.00158 | 0.00682 | 0.04356 |
| Year 7 | 0.00172 | 0.00702 | 0.04404 |
| Year 8 | 0.00128 | 0.00558 | 0.04048 |
| Year 9 | 0.00096 | 0.00497 | 0.03882 |

**Appendix 6 continued. Industry Summaries – Structural Model**

2 Capital Goods; Chemicals

| Capital Goods | | | |
|---|---|---|---|
| Number of Companies | | | 27 |
| Total Debt ($m) | | | 8,461.9 |
| Undiversified Standard Deviation | | | 0.20615 |
| Undiversified Calibrated PD | | | 0.00385 |
| Diversified Standard Deviation | | | 0.10591 |
| Diversified Calibrated PD | | | 0.00001 |
| Calibrated CPD | | | 0.03539 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00001 | 0.00385 | 0.03539 |
| Year 2 | 0.00004 | 0.00407 | 0.03610 |
| Year 3 | 0.00009 | 0.00563 | 0.04061 |
| Year 4 | 0.00016 | 0.00613 | 0.04189 |
| Year 5 | 0.00015 | 0.00576 | 0.04095 |
| Year 6 | 0.00010 | 0.00465 | 0.03787 |
| Year 7 | 0.00002 | 0.00568 | 0.04073 |
| Year 8 | 0.00002 | 0.00534 | 0.03984 |
| Year 9 | 0.00006 | 0.00571 | 0.04082 |

| Chemicals | | | |
|---|---|---|---|
| Number of Companies | | | 6 |
| Total Debt ($m) | | | 3,111.2 |
| Undiversified Standard Deviation | | | 0.18505 |
| Undiversified Calibrated PD | | | 0.00309 |
| Diversified Standard Deviation | | | 0.13575 |
| Diversified Calibrated PD | | | 0.00038 |
| Calibrated CPD | | | 0.03271 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00038 | 0.00309 | 0.03271 |
| Year 2 | 0.00038 | 0.00356 | 0.03440 |
| Year 3 | 0.00016 | 0.00242 | 0.03001 |
| Year 4 | 0.00046 | 0.00326 | 0.03334 |
| Year 5 | 0.00121 | 0.00676 | 0.04342 |
| Year 6 | 0.00080 | 0.00738 | 0.04485 |
| Year 7 | 0.00066 | 0.00711 | 0.04424 |
| Year 8 | 0.00028 | 0.00366 | 0.03475 |
| Year 9 | 0.00025 | 0.00336 | 0.03370 |

**Appendix 6 continued. Industry Summaries – Structural Model**

3 Commercial Services & Supplies; Construction Materials

| Commercial Services & Supplies | | | |
|---|---|---|---|
| Number of Companies | | | 26 |
| Total Debt ($m) | | | 9,152.3 |
| Undiversified Standard Deviation | | | 0.23173 |
| Undiversified Calibrated PD | | | 0.00570 |
| Diversified Standard Deviation | | | 0.10517 |
| Diversified Calibrated PD | | | 0.00001 |
| Calibrated CPD | | | 0.04225 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00001 | 0.00570 | 0.04080 |
| Year 2 | 0.00000 | 0.00441 | 0.03717 |
| Year 3 | 0.00001 | 0.00853 | 0.04733 |
| Year 4 | 0.00003 | 0.01026 | 0.05070 |
| Year 5 | 0.00001 | 0.00677 | 0.04344 |
| Year 6 | 0.00001 | 0.00370 | 0.03489 |
| Year 7 | 0.00001 | 0.00248 | 0.03024 |
| Year 8 | 0.00002 | 0.00194 | 0.02777 |
| Year 9 | 0.00002 | 0.00179 | 0.02699 |

| Construction Materials | | | |
|---|---|---|---|
| Number of Companies | | | 5 |
| Total Debt ($m) | | | 4,343.5 |
| Undiversified Standard Deviation | | | 0.21447 |
| Undiversified Calibrated PD | | | 0.00092 |
| Diversified Standard Deviation | | | 0.15538 |
| Diversified Calibrated PD | | | 0.00004 |
| Calibrated CPD | | | 0.02771 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00004 | 0.00092 | 0.02143 |
| Year 2 | 0.00001 | 0.00049 | 0.01732 |
| Year 3 | 0.00001 | 0.00084 | 0.02077 |
| Year 4 | 0.00001 | 0.00116 | 0.02317 |
| Year 5 | 0.00017 | 0.00330 | 0.03350 |
| Year 6 | 0.00009 | 0.00282 | 0.03166 |
| Year 7 | 0.00032 | 0.00609 | 0.04178 |
| Year 8 | 0.00044 | 0.00277 | 0.03147 |
| Year 9 | 0.00042 | 0.00285 | 0.03178 |

**Appendix 6 continued. Industry Summaries – Structural Model**

4 Consumer Durables & Apparel; Diversified Financials

| Consumer Durables & Apparel | | | |
|---|---|---|---|
| Number of Companies | | | 7 |
| Total Debt ($m) | | | 681.4 |
| Undiversified Standard Deviation | | | 0.26494 |
| Undiversified Calibrated PD | | | 0.00241 |
| Diversified Standard Deviation | | | 0.19442 |
| Diversified Calibrated PD | | | 0.00025 |
| Calibrated CPD | | | 0.02993 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00025 | 0.00241 | 0.02993 |
| Year 2 | 0.00030 | 0.00304 | 0.03254 |
| Year 3 | 0.00015 | 0.00653 | 0.04288 |
| Year 4 | 0.00050 | 0.01165 | 0.05319 |
| Year 5 | 0.00115 | 0.01003 | 0.05028 |
| Year 6 | 0.00046 | 0.00622 | 0.04212 |
| Year 7 | 0.00000 | 0.00056 | 0.01807 |
| Year 8 | 0.00470 | 0.02294 | 0.06907 |
| Year 9 | 0.00215 | 0.01674 | 0.06109 |

| Diversified Financials | | | |
|---|---|---|---|
| Number of Companies | | | 40 |
| Total Debt ($m) | | | 85,907.0 |
| Undiversified Standard Deviation | | | 0.08283 |
| Undiversified Calibrated PD | | | 0.00051 |
| Diversified Standard Deviation | | | 0.03973 |
| Diversified Calibrated PD | | | 0.00000 |
| Calibrated CPD | | | 0.01751 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00000 | 0.00051 | 0.01751 |
| Year 2 | 0.00000 | 0.00053 | 0.01773 |
| Year 3 | 0.00000 | 0.00081 | 0.02048 |
| Year 4 | 0.00000 | 0.00126 | 0.02389 |
| Year 5 | 0.00000 | 0.00129 | 0.02406 |
| Year 6 | 0.00000 | 0.00056 | 0.01814 |
| Year 7 | 0.00000 | 0.00080 | 0.02042 |
| Year 8 | 0.00000 | 0.00091 | 0.02131 |
| Year 9 | 0.00000 | 0.00097 | 0.02185 |

**Appendix 6 continued. Industry Summaries – Structural Model**

5 Energy; Food & Staples Retailing

| Energy | | | |
|---|---|---|---|
| Number of Companies | | | 34 |
| Total Debt ($m) | | | 14,237.4 |
| Undiversified Standard Deviation | | | 0.28111 |
| Undiversified Calibrated PD | | | 0.00207 |
| Diversified Standard Deviation | | | 0.13608 |
| Diversified Calibrated PD | | | 0.00000 |
| Calibrated CPD | | | 0.02840 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00000 | 0.00207 | 0.02840 |
| Year 2 | 0.00000 | 0.00218 | 0.02889 |
| Year 3 | 0.00000 | 0.00299 | 0.03235 |
| Year 4 | 0.00000 | 0.00312 | 0.03283 |
| Year 5 | 0.00000 | 0.00249 | 0.03028 |
| Year 6 | 0.00000 | 0.00194 | 0.02773 |
| Year 7 | 0.00001 | 0.00203 | 0.02820 |
| Year 8 | 0.00000 | 0.00193 | 0.02768 |
| Year 9 | 0.00000 | 0.00181 | 0.02708 |

| Food & Staples Retailing | | | |
|---|---|---|---|
| Number of Companies | | | 6 |
| Total Debt ($m) | | | 13,520.8 |
| Undiversified Standard Deviation | | | 0.16407 |
| Undiversified Calibrated PD | | | 0.00147 |
| Diversified Standard Deviation | | | 0.10853 |
| Diversified Calibrated PD | | | 0.00003 |
| Calibrated CPD | | | 0.02521 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00003 | 0.00147 | 0.02521 |
| Year 2 | 0.00006 | 0.00216 | 0.02879 |
| Year 3 | 0.00013 | 0.00353 | 0.03431 |
| Year 4 | 0.00032 | 0.00438 | 0.03707 |
| Year 5 | 0.00035 | 0.00429 | 0.03678 |
| Year 6 | 0.00009 | 0.00295 | 0.03218 |
| Year 7 | 0.00036 | 0.00205 | 0.02829 |
| Year 8 | 0.00029 | 0.00166 | 0.02628 |
| Year 9 | 0.00026 | 0.00146 | 0.02513 |

**Appendix 6 continued. Industry Summaries – Structural Model**

6 Food Beverage & Tobacco; Healthcare Equipment & Services

| Food Beverage & Tobacco | | | |
|---|---|---|---|
| Number of Companies | | | 15 |
| Total Debt ($m) | | | 11,744.7 |
| Undiversified Standard Deviation | | | 0.15026 |
| Undiversified Calibrated PD | | | 0.00217 |
| Diversified Standard Deviation | | | 0.07601 |
| Diversified Calibrated PD | | | 0.00000 |
| Calibrated CPD | | | 0.02887 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00000 | 0.00217 | 0.02887 |
| Year 2 | 0.00000 | 0.00345 | 0.03404 |
| Year 3 | 0.00003 | 0.00599 | 0.04154 |
| Year 4 | 0.00007 | 0.00754 | 0.04520 |
| Year 5 | 0.00008 | 0.00704 | 0.04408 |
| Year 6 | 0.00007 | 0.00622 | 0.04212 |
| Year 7 | 0.00012 | 0.00716 | 0.04436 |
| Year 8 | 0.00014 | 0.00709 | 0.04419 |
| Year 9 | 0.00037 | 0.00822 | 0.04668 |

| Healthcare Equipment & Services | | | |
|---|---|---|---|
| Number of Companies | | | 17 |
| Total Debt ($m) | | | 4,347.4 |
| Undiversified Standard Deviation | | | 0.22336 |
| Undiversified Calibrated PD | | | 0.00309 |
| Diversified Standard Deviation | | | 0.09721 |
| Diversified Calibrated PD | | | 0.00000 |
| Calibrated CPD | | | 0.03270 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00000 | 0.00309 | 0.03270 |
| Year 2 | 0.00000 | 0.00417 | 0.03641 |
| Year 3 | 0.00000 | 0.00567 | 0.04072 |
| Year 4 | 0.00000 | 0.00756 | 0.04526 |
| Year 5 | 0.00000 | 0.00714 | 0.04432 |
| Year 6 | 0.00001 | 0.00548 | 0.04022 |
| Year 7 | 0.00001 | 0.00585 | 0.04118 |
| Year 8 | 0.00002 | 0.00541 | 0.04002 |
| Year 9 | 0.00008 | 0.00676 | 0.04343 |

**Appendix 6 continued. Industry Summaries – Structural Model**

7 Hotels Restaurants & Leisure; Insurance

| Hotels Restaurants & Leisure | | | |
|---|---|---|---|
| Number of Companies | | | 10 |
| Total Debt ($m) | | | 3,980.6 |
| Undiversified Standard Deviation | | | 0.24654 |
| Undiversified Calibrated PD | | | 0.00237 |
| Diversified Standard Deviation | | | 0.14999 |
| Diversified Calibrated PD | | | 0.00003 |
| Calibrated CPD | | | 0.02977 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00003 | 0.00237 | 0.02977 |
| Year 2 | 0.00007 | 0.00452 | 0.03751 |
| Year 3 | 0.00002 | 0.00283 | 0.03172 |
| Year 4 | 0.00003 | 0.00331 | 0.03353 |
| Year 5 | 0.00002 | 0.00293 | 0.03209 |
| Year 6 | 0.00003 | 0.00320 | 0.03313 |
| Year 7 | 0.00002 | 0.00298 | 0.03229 |
| Year 8 | 0.00002 | 0.00330 | 0.03349 |
| Year 9 | 0.00003 | 0.00074 | 0.01990 |

| Insurance | | | |
|---|---|---|---|
| Number of Companies | | | 7 |
| Total Debt ($m) | | | 147,597.3 |
| Undiversified Standard Deviation | | | 0.09377 |
| Undiversified Calibrated PD | | | 0.04219 |
| Diversified Standard Deviation | | | 0.05937 |
| Diversified Calibrated PD | | | 0.01590 |
| Calibrated CPD | | | 0.08826 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.01590 | 0.04219 | 0.08826 |
| Year 2 | 0.01786 | 0.04600 | 0.09149 |
| Year 3 | 0.01809 | 0.04749 | 0.09270 |
| Year 4 | 0.01935 | 0.04982 | 0.09457 |
| Year 5 | 0.01637 | 0.04152 | 0.08769 |
| Year 6 | 0.01737 | 0.03675 | 0.08341 |
| Year 7 | 0.02483 | 0.04639 | 0.09180 |
| Year 8 | 0.03590 | 0.05330 | 0.09729 |
| Year 9 | 0.06114 | 0.07451 | 0.11230 |

**Appendix 6 continued. Industry Summaries – Structural Model**

8 Media; Metals & Mining

| Media | |
|---|---|
| Number of Companies | 18 |
| Total Debt ($m) | 9,876.7 |
| Undiversified Standard Deviation | 0.18980 |
| Undiversified Calibrated PD | 0.00156 |
| Diversified Standard Deviation | 0.09649 |
| Diversified Calibrated PD | 0.00000 |
| Calibrated CPD | 0.02573 |

| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
|---|---|---|---|
| Year 1 | 0.00000 | 0.00156 | 0.02573 |
| Year 2 | 0.00000 | 0.00179 | 0.02697 |
| Year 3 | 0.00000 | 0.00253 | 0.03047 |
| Year 4 | 0.00001 | 0.00303 | 0.03247 |
| Year 5 | 0.00003 | 0.00397 | 0.03578 |
| Year 6 | 0.00001 | 0.00300 | 0.03237 |
| Year 7 | 0.00006 | 0.00497 | 0.03881 |
| Year 8 | 0.00002 | 0.00390 | 0.03555 |
| Year 9 | 0.00002 | 0.00250 | 0.03034 |

| Metals & Mining | |
|---|---|
| Number of Companies | 64 |
| Total Debt ($m) | 44,994.3 |
| Undiversified Standard Deviation | 0.25705 |
| Undiversified Calibrated PD | 0.00382 |
| Diversified Standard Deviation | 0.15539 |
| Diversified Calibrated PD | 0.00009 |
| Calibrated CPD | 0.03528 |

| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
|---|---|---|---|
| Year 1 | 0.00009 | 0.00382 | 0.03528 |
| Year 2 | 0.00007 | 0.00394 | 0.03567 |
| Year 3 | 0.00008 | 0.00517 | 0.03936 |
| Year 4 | 0.00009 | 0.00593 | 0.04139 |
| Year 5 | 0.00013 | 0.00611 | 0.04183 |
| Year 6 | 0.00005 | 0.00407 | 0.03609 |
| Year 7 | 0.00003 | 0.00398 | 0.03582 |
| Year 8 | 0.00001 | 0.00231 | 0.02953 |
| Year 9 | 0.00000 | 0.00173 | 0.02666 |

**Appendix 6 continued. Industry Summaries – Structural Model**

9 Paper & Forest Products; Pharmaceuticals & Biotechnology

| Paper & Forest Products | | | |
|---|---|---|---|
| Number of Companies | | | 8 |
| Total Debt ($m) | | | 3,427.1 |
| Undiversified Standard Deviation | | | 0.22850 |
| Undiversified Calibrated PD | | | 0.01720 |
| Diversified Standard Deviation | | | 0.12346 |
| Diversified Calibrated PD | | | 0.00109 |
| Calibrated CPD | | | 0.06174 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00109 | 0.01720 | 0.06174 |
| Year 2 | 0.00084 | 0.01677 | 0.06114 |
| Year 3 | 0.00019 | 0.01075 | 0.05161 |
| Year 4 | 0.00012 | 0.00785 | 0.04589 |
| Year 5 | 0.00023 | 0.00746 | 0.04503 |
| Year 6 | 0.00042 | 0.00802 | 0.04625 |
| Year 7 | 0.00037 | 0.00794 | 0.04609 |
| Year 8 | 0.00076 | 0.00817 | 0.04658 |
| Year 9 | 0.00033 | 0.00646 | 0.04271 |

| Pharmaceuticals & Biotechnology | | | |
|---|---|---|---|
| Number of Companies | | | 23 |
| Total Debt ($m) | | | 2,640.3 |
| Undiversified Standard Deviation | | | 0.34561 |
| Undiversified Calibrated PD | | | 0.00625 |
| Diversified Standard Deviation | | | 0.18957 |
| Diversified Calibrated PD | | | 0.00010 |
| Calibrated CPD | | | 0.04218 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00010 | 0.00625 | 0.04218 |
| Year 2 | 0.00002 | 0.00760 | 0.04535 |
| Year 3 | 0.00002 | 0.01095 | 0.05196 |
| Year 4 | 0.00002 | 0.01488 | 0.05839 |
| Year 5 | 0.00010 | 0.01249 | 0.05462 |
| Year 6 | 0.00006 | 0.00473 | 0.03812 |
| Year 7 | 0.00004 | 0.00444 | 0.03726 |
| Year 8 | 0.00000 | 0.00392 | 0.03562 |
| Year 9 | 0.00000 | 0.00368 | 0.03483 |

**Appendix 6 continued. Industry Summaries – Structural Model**

10 Real Estate; Retailing

| Real Estate | | | |
|---|---|---|---|
| Number of Companies | | | 54 |
| Total Debt ($m) | | | 43,059.9 |
| Undiversified Standard Deviation | | | 0.15200 |
| Undiversified Calibrated PD | | | 0.00055 |
| Diversified Standard Deviation | | | 0.07099 |
| Diversified Calibrated PD | | | 0.00000 |
| Calibrated CPD | | | 0.01797 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00000 | 0.00055 | 0.01797 |
| Year 2 | 0.00000 | 0.00081 | 0.02055 |
| Year 3 | 0.00000 | 0.00094 | 0.02160 |
| Year 4 | 0.00000 | 0.00111 | 0.02284 |
| Year 5 | 0.00000 | 0.00119 | 0.02344 |
| Year 6 | 0.00000 | 0.00110 | 0.02276 |
| Year 7 | 0.00000 | 0.00126 | 0.02390 |
| Year 8 | 0.00000 | 0.00102 | 0.02219 |
| Year 9 | 0.00000 | 0.00111 | 0.02283 |

| Retailing | | | |
|---|---|---|---|
| Number of Companies | | | 20 |
| Total Debt ($m) | | | 3,118.1 |
| Undiversified Standard Deviation | | | 0.21959 |
| Undiversified Calibrated PD | | | 0.00829 |
| Diversified Standard Deviation | | | 0.12125 |
| Diversified Calibrated PD | | | 0.00021 |
| Calibrated CPD | | | 0.04684 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00021 | 0.00829 | 0.04684 |
| Year 2 | 0.00013 | 0.00734 | 0.04476 |
| Year 3 | 0.00000 | 0.00194 | 0.02776 |
| Year 4 | 0.00043 | 0.00890 | 0.04808 |
| Year 5 | 0.00049 | 0.00795 | 0.04611 |
| Year 6 | 0.00044 | 0.00586 | 0.04121 |
| Year 7 | 0.00050 | 0.00446 | 0.03731 |
| Year 8 | 0.00021 | 0.00235 | 0.02969 |
| Year 9 | 0.00006 | 0.00189 | 0.02747 |

**Appendix 6 continued. Industry Summaries – Structural Model**

11 Software & Services; Technology Hardware & Equipment

| Software & Services | | | |
|---|---|---|---|
| Number of Companies | | | 18 |
| Total Debt ($m) | | | 1,284.1 |
| Undiversified Standard Deviation | | | 0.44131 |
| Undiversified Calibrated PD | | | 0.01758 |
| Diversified Standard Deviation | | | 0.22815 |
| Diversified Calibrated PD | | | 0.00084 |
| Calibrated CPD | | | 0.06225 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00084 | 0.01758 | 0.06225 |
| Year 2 | 0.00082 | 0.01962 | 0.06496 |
| Year 3 | 0.00054 | 0.02323 | 0.06941 |
| Year 4 | 0.00092 | 0.02898 | 0.07578 |
| Year 5 | 0.00031 | 0.01954 | 0.06486 |
| Year 6 | 0.00008 | 0.00899 | 0.04826 |
| Year 7 | 0.00676 | 0.02269 | 0.06877 |
| Year 8 | 0.00423 | 0.01815 | 0.06303 |
| Year 9 | 0.00109 | 0.00679 | 0.04350 |

| Technology Hardware & Equipment | | | |
|---|---|---|---|
| Number of Companies | | | 9 |
| Total Debt ($m) | | | 686.4 |
| Undiversified Standard Deviation | | | 0.42422 |
| Undiversified Calibrated PD | | | 0.02947 |
| Diversified Standard Deviation | | | 0.21511 |
| Diversified Calibrated PD | | | 0.00295 |
| Calibrated CPD | | | 0.07629 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00295 | 0.02947 | 0.07629 |
| Year 2 | 0.00161 | 0.03302 | 0.07987 |
| Year 3 | 0.00326 | 0.04044 | 0.08674 |
| Year 4 | 0.02176 | 0.06320 | 0.10460 |
| Year 5 | 0.04020 | 0.06815 | 0.10804 |
| Year 6 | 0.03441 | 0.05690 | 0.10002 |
| Year 7 | 0.03618 | 0.04752 | 0.09272 |
| Year 8 | 0.02939 | 0.03908 | 0.08553 |
| Year 9 | 0.03791 | 0.04384 | 0.08968 |

**Appendix 6 continued. Industry Summaries – Structural Model**

12 Telecommunication Services; Transportation

| Telecommunication Services | | | |
|---|---|---|---|
| Number of Companies | | | 6 |
| Total Debt ($m) | | | 16,202.5 |
| Undiversified Standard Deviation | | | 0.15653 |
| Undiversified Calibrated PD | | | 0.00223 |
| Diversified Standard Deviation | | | 0.14665 |
| Diversified Calibrated PD | | | 0.00150 |
| Calibrated CPD | | | 0.02913 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00150 | 0.00223 | 0.02913 |
| Year 2 | 0.00130 | 0.00198 | 0.02797 |
| Year 3 | 0.00254 | 0.00376 | 0.03510 |
| Year 4 | 0.00328 | 0.00535 | 0.03987 |
| Year 5 | 0.00471 | 0.00637 | 0.04248 |
| Year 6 | 0.00571 | 0.00814 | 0.04651 |
| Year 7 | 0.00119 | 0.00707 | 0.04415 |
| Year 8 | 0.00002 | 0.00032 | 0.01502 |
| Year 9 | 0.00293 | 0.00595 | 0.04144 |

| Transportation | | | |
|---|---|---|---|
| Number of Companies | | | 10 |
| Total Debt ($m) | | | 19,176.6 |
| Undiversified Standard Deviation | | | 0.16435 |
| Undiversified Calibrated PD | | | 0.00426 |
| Diversified Standard Deviation | | | 0.08458 |
| Diversified Calibrated PD | | | 0.00002 |
| Calibrated CPD | | | 0.03671 |
| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
| Year 1 | 0.00002 | 0.00426 | 0.03671 |
| Year 2 | 0.00001 | 0.00404 | 0.03602 |
| Year 3 | 0.00002 | 0.00470 | 0.03802 |
| Year 4 | 0.00008 | 0.00627 | 0.04224 |
| Year 5 | 0.00004 | 0.00700 | 0.04398 |
| Year 6 | 0.00012 | 0.00569 | 0.04076 |
| Year 7 | 0.00007 | 0.00405 | 0.03604 |
| Year 8 | 0.00006 | 0.00242 | 0.03001 |
| Year 9 | 0.00017 | 0.00280 | 0.03160 |

**Appendix 6 continued. Industry Summaries – Structural Model**

13 Utilities

| Utilities | |
|---|---|
| Number of Companies | 10 |
| Total Debt ($m) | 8,862.7 |
| Undiversified Standard Deviation | 0.12007 |
| Undiversified Calibrated PD | 0.00009 |
| Diversified Standard Deviation | 0.06500 |
| Diversified Calibrated PD | 0.00000 |
| Calibrated CPD | 0.01005 |

| | Historical Diversified Calibrated PD: | Historical Undiversified Calibrated PD: | Historical Calibrated CPD: |
|---|---|---|---|
| Year 1 | 0.00000 | 0.00009 | 0.01005 |
| Year 2 | 0.00000 | 0.00007 | 0.00894 |
| Year 3 | 0.00000 | 0.00047 | 0.01707 |
| Year 4 | 0.00000 | 0.00056 | 0.01810 |
| Year 5 | 0.00000 | 0.00066 | 0.01912 |
| Year 6 | 0.00001 | 0.00155 | 0.02565 |
| Year 7 | 0.00003 | 0.00150 | 0.02534 |
| Year 8 . | 0.00001 | 0.00146 | 0.02515 |
| Year 9 | 0.00002 | 0.00114 | 0.02305 |

# Appendix 7. Working Paper Abstracts

This Appendix provides the abstracts for the working papers that have been written from this study. These papers have been submitted to various international and local conferences and journals for presentation and / or publication.

## Paper 1: INDUSTRY MARKET VALUE AT RISK AND CONDITIONAL VALUE AT RISK IN AUSTRALIA

**Abstract:**

Value at Risk (VaR) is an important issue for banks since its adoption as a primary risk metric in the Basel Accords and the requirement that it is calculated on a daily basis. Relative industry risk measurement is also very important to Banks in their management of risk, such as for setting risk concentration limits and developing investment and credit policy.

This paper examines market Value at Risk (VaR) and Conditional VaR (CVaR) in Australia from an industry perspective using a set of Australian industries. VaR and CVaR are compared between these industries over time, and a variety of metrics are used including diversified and undiversified VaR, as well as parametric and nonparametric CVaR methods. There has been no prior investigation of industry based VaR metrics in Australia to the authors' knowledge. The relative riskiness of different industry sectors is examined and using diversified VaR, the study finds the highest risk is in the Technology Sectors, whilst the lowest risk is found in the Finance and Utilities Sectors. Composite riskiness is also explored and the existence of correlation between industry risk rankings over time is found to depend on the number of years of data used. There is evidence of rank correlation over time using a 7 year window approach, but not when using 1 year data tranches. This highlights the importance of using both short and long time frames in order to cover different economic cycles as well as consider current conditions.

It is important to note that, using a 7 year time frame, there is found to be no significant difference between diversified and undiversified industry VaR rankings, or between parametric and nonparametric CVaR approaches. This means that, provided a sufficiently long time period is used, bankers can be reasonably confident of the robustness and consistency of these metrics when calculating and applying them over time and across industries.

**Appendix 7 continued**

## Paper 2: STRUCTURAL CREDIT MODELLING AND ITS' RELATIONSHIP TO MARKET VALUE AT RISK: AN AUSTRALIAN SECTORAL PERSPECTIVE

**Abstract:**

Credit risk modelling has become increasingly important to Banks since the advent of Basel II which allows Banks with sophisticated modelling techniques to use internal models for the purpose of calculating capital requirements. A high level of credit risk is often the key reason behind banks failing or experiencing severe difficulty. The management of sectoral concentration is a critical component of credit risk management, as over concentration of credit in sectors can be a significant contributor to difficulties experienced by banks.

Conditional Value at Risk (CVaR) is gaining popularity as a measurement of credit risk, with the recognition that high lending losses are often impacted by a small number of extreme events.

This study examines sectoral probability of default (PD) in an Australian context based on the Structural approach of Merton (1974), and more recently modified and popularised by KMV Corporation (Crosbie & Bohn, 2003). In addition to examining PD, we introduce a CVaR type component into Structural modelling which we term conditional probability of default (CPD). We also examine the interaction between sectoral credit and market risk using VaR and CVaR models for market risk, and PD and CPD models for credit risk. Significant rank correlation is found between all of the approaches used, showing that those sectors which are risky from a credit perspective are not significantly different from those which are risky from a market perspective.

**Appendix 7 continued**

**Paper 3: TRANSITIONAL CREDIT MODELLING AND ITS' RELATIONSHIP TO MARKET VALUE AT RISK: AN AUSTRALIAN SECTORAL PERSPECTIVE**

**Abstract:**

Internal credit risk modelling is not only important to banks for the calculation of capital adequacy in terms of the Basel Accords, but also for the management of portfolio risks such as over concentration of sectoral exposure, which is a key contributor to credit losses experienced by banks.

This study focuses on industry risk in an Australian context using the Transition Matrix approach based on CreditMetrics methodology. In addition to VaR, we examine Conditional VaR (CVaR) which measures extreme risk and is gaining popularity as a measure of credit risk with the recognition that lending losses are often impacted by extreme events. New CVaR techniques are introduced in this study and compared to existing methodology. This provides banks with a range of methodologies for measuring extreme risk. Significant association is found between the different CVaR methods, showing simpler methods to be viable alternatives to more complex methodology.

We also examine the CreditPortfolioView model which incorporates industry risk differentiation into a Transition framework using macroeconomic factors. Whilst industry considerations are very important to banks in modelling credit risk, a study in Australia has shown that incorporation of macroeconomic factors into credit modelling is not favoured by banks. To overcome this problem, we examine the relationship between market and credit risk, and use this relationship to develop a new model that allows the incorporation of market modelled industry VaR factors into Transition modelling, without using macroeconomic analysis.